DRAFT FEASIBILITY STUDY REPORT
PATRICK BAYOU SUPERFUND SITE
DEER PARK, TEXAS

Prepared for

Patrick Bayou Joint Defense Group

U.S. Environmental Protection Agency

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	activated carbon
ACBM	articulated concrete block mat
ACT	Antiquities Code of Texas
Anchor QEA	Anchor QEA, LLC
AOC	Administrative Order on Consent
APE	Area of Potential Effect
ARAR	Applicable or Relevant and Appropriate Requirement
AVS	acid volatile sulfide
BEHP	bis(2-ethylhexyl) phthalate
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BMP	best management practice
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
CNRA	coastal natural resource area
COC	chemical of concern
COPC	chemical of potential concern
CSM	Conceptual Site Model
CWA	Clean Water Act
ESA	Endangered Species Act
FR	Federal Register
FS	Feasibility Study
GLO	Texas General Land Office
GRA	General Response Action
HSC	Houston Ship Channel
HQ	hazard quotient
IC	indicator chemical

JDG	Joint Defense Group
LOE	line-of-evidence
Lubrizol	The Lubrizol Corporation
MHW	mean high water
MNR	Monitored Natural Recovery
MOA	Memorandum of Agreement
NCP	National Contingency Plan
ng/L	nanograms per liter
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPV	net present value
NRHP	National Register of Historic Places
NSR	net sedimentation rate
OMM	operations, monitoring, and maintenance
Oxy	Occidental Chemical Corporation
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PEL-Q	Probable Effects Level-Quotient
PHA	Port of Houston Authority
PRG	preliminary remediation goal
PSCR	Preliminary Site Characterization Report
RAL	remedial action level
RAO	Remedial Action Objective
RATS	Remedial Action Technology Screening
RCM	Reactive Core Mat
RI	Remedial Investigation
SEM	simultaneously extracted metal
SH	State Highway

Shell	Shell Oil Company, on behalf of Deer Park Refining Limited Partnership and Shell Chemical, LLP
SHPO	State Historic Preservation Officer
Site	Patrick Bayou Superfund Site
SMA	sediment management area
SOW	Statement of Work
STM	sediment transport model
TBC	to be considered
TCEQ	Texas Commission on Environmental Quality
TEF	toxic equivalency factor
TEQ	toxic equivalent
TMDL	Total Maximum Daily Load
TMV	toxicity, mobility or volume
TOB	top of bank
TPDES	Texas Pollutant Discharge Elimination System
TSWQS	Texas Surface Water Quality Standards
USDL	U.S. Department of Labor
USEPA	U.S. Environmental Protection Agency
WOE	weight-of-evidence

1 INTRODUCTION

This draft *Feasibility Study Report* (FS) was prepared for the Patrick Bayou Superfund Site (Site) in Deer Park, Texas (Figure 1-1) on behalf of the Patrick Bayou Joint Defense Group (JDG)[1]. The work is being conducted under an Administrative Order on Consent (AOC) and Settlement Agreement dated January 31, 2006. This FS builds upon the final *Remedial Alternatives Technology Screening* report (RATS), submitted on May 31, 2013 (Anchor QEA 2013a), which outlined the general approach of the FS. The RATS also provides additional background information and detailed analysis in support of the FS.

This FS develops and evaluates remedial alternatives for the Site based on the Remedial Action Objectives (RAOs) provided in the RATS and the *Remedial Investigation Report* (RI; Anchor QEA 2013b) and the results of the *Baseline Human Health Risk Assessment* (BHHRA; Anchor QEA 2012) and *Baseline Ecological Risk Assessment* (BERA; Anchor QEA 2013c). This FS was prepared by Anchor QEA, LLC (Anchor QEA), under the direction of the U.S. Environmental Protection Agency (USEPA) and JDG.

Each draft remedial alternative is based on the USEPA-approved Adaptive Management approach (USEPA 2006). Adaptive management involves making, evaluating, and modifying (if appropriate) decisions in a phased manner so that future actions can be optimized to reflect knowledge that is gained over time. For purposes of this FS, adaptive management would allow remedy(s) to be implemented in stages as their effectiveness in achieving RAOs is evaluated.

1.1 Purpose and Organization of the Report

The purpose of the FS Report is to describe the development and evaluation of remedial alternatives that will be used in support of the selection of a remedy to address the previously identified RAOs and mitigate potential risks to the environment posed by the Site. This FS was conducted in accordance with USEPA guidance (USEPA 1988).

[1] The Patrick Bayou JDG includes the Respondents to the AOC and Settlement Agreement dated January 31, 2006 for the Remedial Investigation/Feasibility Study (RI/FS). The JDG includes The Lubrizol Corporation (Lubrizol), Occidental Chemical Corporation (Oxy), and Shell Oil Company (Shell), on behalf of Deer Park Refining Limited Partnership and Shell Chemical, LLP.

The remainder of Section 1 provides a summary of the regulatory background for the Site. Section 2 provides a summary of Site information as presented in previous documents prepared and submitted in support of the RI/FS process, including a summary of Site setting and history, the nature and extent of contamination, contaminant fate and transport characteristics at the Site, and the results of the BERA and BHHRA. The other sections of this FS address the following:

- Section 3 identifies the remedial action levels (RALs) and basis for the remedial action
- Section 4 describes the development of each alternative
- Section 5 provides a detailed and comparative analysis of each alternative
- Section 6 provides the comparative evaluation of alternatives and describes the recommended alternative
- Section 7 provides the references
- Appendix A describes chemical fate and transport modeling
- Appendix B describes cap chemical and erosion modeling
- Appendix C provides details on estimated costs for the remedial alternatives
- Appendix D describes the 2014 surface water data collection, including results
- Appendix E describes analytical modeling of natural recovery of polychlorinated biphenyls (PCBs) in surface water
- Appendix F provides an evaluation of institutional controls

1.2 Regulatory Background

Patrick Bayou was proposed for addition to the National Priorities List (NPL) (*Federal Register* [FR], volume 66, page 32,287) on June 14, 2001, based on ranking developed using the Hazard Ranking System, which USEPA promulgated as Appendix A of the National Contingency Plan (NCP) (*Code of Federal Regulations* [CFR], Title 40 Part 300). The Site listing was finalized on September 5, 2002 (67 FR 56747) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. The RI/FS for the Site is required by the AOC and Settlement Agreement with the USEPA dated January 31, 2006, and was developed in accordance with the Statement of Work (SOW) attached to the AOC.

This FS Report was prepared to satisfy the requirements of Task 7 in the SOW for the submittal of a Draft FS following receipt of USEPA approval of the final RI (Anchor QEA 2013b). The FS will ultimately lead to a proposed remedial action plan for the Site. This report was prepared in accordance with *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988).

2 BACKGROUND INFORMATION

This section provides a summary of information gathered during the RI concerning physical, chemical, and biological characteristics of the Site, as well as sources, nature and extent of contamination, and fate and transport process. This information is intended to provide the reader with an understanding of the Site and the human actions, natural processes, and physical properties that may influence the nature and extent of chemicals of concern (COCs) at the Site, and that may influence evaluation of remedial alternatives presented in Sections 4 through 6 of this report. A comprehensive description of the physical and biological setting for the Site, as well as a more detailed history of the Site, Site uses, the nature and extent of contaminants, and important fate and transport processes, are provided in the RI Report (Anchor QEA 2013b).

2.1 Site Location and History

Patrick Bayou is a tributary of the Houston Ship Channel (HSC) in Harris County, Texas, (Figure 1-1) that discharges at the south shore of the HSC approximately 2.3 miles upstream of the HSC confluence with the San Jacinto River. The Site itself and its physical features are described in detail in the *Preliminary Site Characterization Report* (PSCR; Anchor 2006) and the RI (Anchor QEA 2013b); a brief summary is provided below.

The Site originates north of State Highway (SH) 225 at the downstream terminus of a set of box culverts that lie underneath the highway and follows the bayou north approximately 10,200 feet to the HSC (Figure 2-1)[2]. The Site itself is bordered by three separate facilities owned by Shell, Lubrizol, and Oxy (Figure 2-2). Upstream of the Site on the south side of SH 225, Patrick Bayou is largely concrete-lined and serves as a drainage system for the City of Deer Park. A City-permitted wastewater discharge enters the Site drainage system in this area approximately 75 feet south of SH 225. The East Fork enters the Site approximately midway between SH 225 and the HSC near Station PB-065 and is the only significant

[2] A station numbering system was developed for the Site for consistency and ease of reference throughout this document and associated figures. In this system, station identifiers are named so the last three numbers in the identifier reflect the station's distance from the mouth of Patrick Bayou in hundreds of feet. For example, the upstream boundary of the Site is at Station PB-102 (10,200 feet from the HSC).

tributary of the Site (Figure 2-1). Rohm and Haas Company and Praxair, Inc., have manufacturing operations upstream and adjacent to the East Fork tributary.

In addition to the City-permitted wastewater discharge, an urban developed area is located within the stormwater watershed that drains through Patrick Bayou. This watershed comprises paved surfaces (e.g., roads, parking lots), railroads, commercial/industrial facilities, recreational areas (e.g., athletic fields, golf courses), agricultural/undeveloped areas, and residential areas. Review of readily available information for this area in federal and state databases identified 130 facility registrations, and numerous other retail/commercial/industrial facilities that can potentially discharge chemical and non-chemical stressors to the Site.

Patrick Bayou was named for the original 1838 grantee for the land around the bayou, George M. Patrick (Texas Land Grant Office 2013). Deer Park was developed in 1892 by land promoters hoping for Midwestern farmer settlement (Laird 2008), and a railroad station was soon established nearby. The new community grew, and later experienced a great expansion in the 1940s, when Deer Park became the site for various refineries and toluol (toluene) plants (Kleiner 2013), including those that border the Site. Shell's refinery began operation in 1929 and was the first manufacturer to be based in Deer Park. OxyVinyls, LP, (OxyVinyls) is a subsidiary of Oxy. The OxyVinyls Deer Park facility began operation in 1948. The Lubrizol Deer Park facility has been in operation since 1951.

2.2 Aquatic Land Ownership

The aquatic lands within the Site below mean high water (MHW) are owned by the State of Texas, and managed by the Texas General Land Office (GLO). In addition to the GLO, the Port of Houston Authority (PHA) has a significant role and authority regarding the ownership of submerged land in Harris County, granted by the Texas Constitution (PHA 2011).

2.3 Land Use

Land use data were obtained from the Houston-Galveston Area Council (Merrick 2008). The Site itself is bounded by industrial facilities (Figure 2-3). Upstream of the Site's watershed, land use is predominantly residential, commercial, and industrial. According to 2010 census data (U.S. Census Bureau 2010), there are no residences within the Patrick Bayou watershed adjacent to the Site (i.e., north of SH 225). Given the long historical record of heavy industrial use, as well as active industrial operations, adjacent land use is not expected to change in the foreseeable future.

2.3.1 Recreational and Navigational Use

Access to and use of the Site is limited to workers authorized by the respective JDG facilities surrounding the Site. Access to the Site by the public is restricted from the uplands by physical controls (e.g., fencing) and strict security/surveillance controls implemented by the industrial facilities along the Site. Unauthorized access by the public (i.e., trespassers) could potentially occur but is considered unlikely (Anchor QEA 2011a).

The Captain of the Port of Houston-Galveston has established navigational security zones for certain areas within the Houston and Galveston area, which include the portion of the HSC that Patrick Bayou enters (USCG 2013). Recreational/unauthorized vessels are excluded from these areas, preventing or discouraging access to the Site through the HSC by recreational or unauthorized vessel traffic. Access to the majority of the Site by water is also blocked by the low bridge and pipe crossings near Station PB-012 (or about 1,200 feet from the HSC). Therefore, the Site affords no opportunities for access, much less recreational use, and is unlikely to do so for the foreseeable future.

2.4 Ecological Conditions

This section describes the general types and quality of habitat present as they relate to species use of and access to the Site. This information is largely summarized from the detail provided in the RI (Anchor QEA 2013b), the BERA Report (Anchor QEA 2013c), the BERA Work Plan (Anchor QEA 2011b), and the PSCR (Anchor 2006).

The Site is bordered by industrial facilities with a developed upland environment. The waterway has been largely channelized and armored, which, when combined with extreme temperature variations, leads to severe limitations in its capacity to provide aquatic ecological functions. However, some areas of the Site are less modified and the waterway is used by several species. The Site provides habitat for bottom-dwelling species (e.g., benthic and epibenthic); foraging and resting opportunities for open-water species (e.g., fish), shorebirds, waterfowl, and other migratory birds; and may also provide foraging or denning opportunities for a variety of small mammalian species that have a higher tolerance for human presence (e.g., raccoons, nutria, rats, and mice).

Natural and human-influenced fluctuations in water flows within the Site influence the species mix inhabiting the waterway. Under typical conditions, Patrick Bayou is a low-gradient tidal stream influenced by daily tides of 1.5 feet or less. Moderate and heavy precipitation events can produce significant flows into Patrick Bayou resulting in rapid changes in salinity, temperature, dissolved oxygen, velocity, and suspended sediment loads in the waterway in the form of stormwater runoff. Conversely, sustained drought can result in significantly higher salinity and temperature regimes and depressed dissolved oxygen levels. Therefore, while tidal ranges are small, flow characteristics at the Site, as discussed below, heavily influence animals inhabiting the water column and sediment surface. A detailed evaluation of the characteristics of these non-contaminant stressors is included in Appendix E-3 of the BERA (Anchor QEA 2013c).

Environmental conditions and bottom substrate conditions significantly influence benthic species that have close associations with sediment and limited home ranges. Studies of the Site evaluating the condition of the benthic community have shown wide variability in benthic species presence and diversity (Anchor 2006) due to widely fluctuating environmental conditions throughout the Site. Thus, while a benthic community that could potentially provide a base for the food chain may be present, its overall health likely reflects both changes in physical Site conditions, as well as potential impacts to Site sediments.

Specifically with respect to the benthic community, this FS considers remedial alternatives to address potential risks to benthic invertebrates inhabiting the surficial sediments at the Site. In order to evaluate the overall appropriateness and efficacy of alternative remedial measures on this community, it is important to consider the nature of this community in the context of the degree to which non-contaminant characteristics affect the composition and stability of the benthic invertebrate community, and the degree to which this community will respond to exposure to contaminants.

As discussed in detail in Appendices E-3 and E-4 of the BERA (Anchor QEA 2013c), the Site is characterized as a mesohaline system with a salinity gradient between the downstream and upstream limits of the Site as a result of stormwater runoff, upstream flow, and tidal effects. The infaunal macroinvertebrates collected in 2000 and 2001 as part of the Total Maximum Daily Load (TMDL) investigations performed at the Site reflect this gradient, and the benthic index developed as part of the BERA (see Appendix E-4 of the BERA; Anchor QEA 2013c) explicitly considered salinity as a determinant of the composition of the benthic community. It is also important to note that, consistent with Gulf of Mexico sites, the benthic community found at the Site tends to be concentrated in the shallowest portion of the sediment column (the upper 1 to 2 cm below the mudline), compared to more northern estuaries (see references in Section 1.1 of Appendix E-3 of the BERA; Anchor QEA 2013c).

Given the environmental conditions at the Site, and the degree to which these conditions can cause rapid physical (e.g., erosion) and chemical (e.g., salinity, dissolved oxygen) changes to the surface water and surficial sediments at the Site, it is clear that the shallow benthic invertebrate community would also be expected to respond relatively quickly to changes in water column and surficial sediment contaminant exposure concentrations. Specifically, as cleaner sediments develop in the upper few centimeters along with cleaner surface waters, exposures to the majority of the benthic invertebrate community will be reduced proportionally. During development and implementation of the pre-design sampling program and as part of remedial design, it will be important to evaluate the degree to which Monitored Natural Recovery (MNR) processes at the Site, including sediment deposition and resuspension and physical and biological mixing of the surface sediments, differentially affect discrete depth zones in the sediment column, particularly the near-surface sediments where the benthic community is most highly concentrated.

Fish and shellfish are found in Patrick Bayou in various natural or modified aquatic zones and generally include species adapted to shallow water conditions. In addition, fish distribution and abundance is associated with the availability of appropriate prey items, temperature, and salinity regime as required for different species. Shellfish, such as juvenile blue crab[3] and shrimp, are generally found at the relatively higher salinity zone near the HSC and are not found in significant numbers in upstream areas of the Site (generally upstream of the East Fork Tributary). The steep gradient and larger grain-size materials (gravels and cobbles) in the concrete-lined channel (also referred to as the "gunite-lined" channel in other documents) also significantly limit the potential for benthic habitat in upstream areas. Given the small size of the Site, wider-foraging or migratory fish would not be expected to spend significant time within the Site but may occasionally forage within Patrick Bayou.

Wildlife habitat at the Site consists of less modified areas of bank and riparian zones of the downstream portions. Riparian conditions range from maintained turf grass to shrub/scrub with sparse tree cover. Natural banks are generally low and gradually sloping, while banks that have been armored are steep and high. Emergent aquatic vegetation is largely absent from the Site. Given the industrial nature of the upland habitat, lack of riparian cover, and modified nature of the shoreline, habitat to support terrestrial mammals is limited. Thus, species that may be present (or have been observed) would include those with limited ranges and urban-adapted characteristics, such as raccoon, muskrat, nutria, mice, and rats.

2.5 Physical Description

The following section presents a physical description of the site including bathymetry and topography, structures, waterway hydrodynamics and streambed characteristics.

2.5.1 Bathymetry and Topography

A bank-to-bank bathymetric survey was conducted in 2005 by Gahagan and Bryant Associates, Inc. for the Site and areas immediately upstream (south of SH 225) and downstream (within the proximal portions of the HSC). The upstream and upper portion of the Site (from the Deer Park Waste Water Treatment Plant [WWTP] outfall to the end of the concrete-lined channel) has a significantly higher hydraulic gradient (about 10 feet of elevation change over 5,000 linear feet) when compared to the middle and lower portions of the Site (less than 1 foot of elevation change over 8,000 linear feet).

[3] Adult blue crab, which can tolerate a higher range of salinity, can be found farther upstream (near the lined channel) than juvenile blue crab under the same conditions.

The channel base elevation between Stations PB-037 and PB-080 (the downstream limit of the concrete-lined channel) generally is not deeper than -3 feet referenced to the North American Vertical Datum of 1988 (NAVD 88). Bank slopes in this area are relatively flat, and transitions between the channel and shoal/deposition areas are poorly defined. Downstream of Station PB-037 to Station PB-028, the bank slopes are steepened slightly, with channel elevations reaching -6 feet NAVD 88. The channel widens downstream of Station PB-028 prior to its intersection with the HSC, and areas of shoaling/deposition and channel flow are more clearly defined. Near the two small islands in the lower portion of the Site (PB-017), the primary channel alignment is offset toward the east bank and transitions to the west bank of the Site. Channel elevations between PB-028 and PB-017 ranges between -2 and -4 feet NAVD 88. Downstream of PB-017, channel elevations generally reach between -4 and -6 feet NAVD 88. The bottom elevation at the Site boundary ranges between -6 and -8 feet NAVD 88.

Stream bank heights in areas with bulkheads and riprap are generally steep with top of bank elevations exceeding 9 feet NAVD 88. Areas without bank modifications, which include much of the middle section of the Site, typically have low, sloping banks with bank elevations less than 6 feet NAVD 88. Bank cover in areas without riprap or bulkheads is generally mowed grass with some low shrubs and bare earth. In many areas, industrial facilities and impervious surfaces, such as parking lots and roads are located adjacent to the banks of the Site.

2.5.2 Adjacent Facilities, Infrastructure, and Waterway Structures

Several fixed structures cross the Site as described in the RATS. A bridge crosses Patrick Bayou from the OxyVinyls facility to a ship offloading area along the channel near the confluence with the HSC. A bridge partially crosses the Site at Station PB-057 (approximate) between the Shell and OxyVinyls facilities, and an overhead, pile supported pipe rack is present approximately 300 feet upstream of this location. There are several overhead pipe racks, a vehicle bridge, and a rail bridge that cross the Site at Stations PB-079 to PB-080.5 (approximate). Additional overhead pipe racks cross the Site at about Station PB-095. Outfalls are present at several locations along the banks of Patrick Bayou. All of these structures physically limit access to the Site by water vessel from the HSC. The channel has concrete lined slopes between Station PB-081 and the upstream end of the Site (Station PB-102).

In addition to the multiple bridge and utility crossings, there are many shoreline structures (e.g., catwalks, sheetpile walls) along the banks of the Site. Overall access to the Site is restricted by the adjacent structures and surrounding facility security systems. The effects of these restrictions are significant and must be considered during remedial design planning.

2.5.3 Waterway Hydrodynamics

Water depths in the Site boundary range from shallow inter-tidal zones (less than 1 foot) to 8 feet at the confluence with the HSC. The Site's open-water system is characteristic of bayous of the coastal Gulf of Mexico, consisting of a tidally influenced secondary stream with sluggish flow during typical conditions. Tides in the HSC are generally weak and exhibit semidiurnal and diurnal components. However, winds and ship traffic within the HSC often disrupt the astronomical tidal cycles and may dominate short-term circulation patterns. Normal tidal ranges (the elevation difference between mean low and mean high water) in the HSC are typically less than 1.5 feet; the mean tidal range of the HSC near Patrick Bayou is 1.2 feet (National Oceanic and Atmospheric Administration [NOAA] 2006). The tidal range at the Site is also affected by flow and wind. During low-flow and wind-driven low tide conditions, the intertidal zone may become dewatered for extended periods (e.g., several days) which is a stressor to the benthic community. Base-flow discharges for the main channel range from about 1 to 100 cubic feet per second (cfs), with an average value of 28 cfs. For the East Fork, base-flow discharge is 2 cfs on average, with a range of about 0.1 to 10 cfs (Anchor QEA 2011c).

2.5.4 Streambed Characteristics and Sediment Transport

A detailed evaluation and analysis of the streambed and sediment transport processes within the Site was presented in the RI (Anchor QEA 2013b), as well as the *Sediment Transport Modeling Report* (STM Report; Anchor QEA 2011c).

The nature of the sediment bed affects sediment transport processes, as well as chemical distributions. The sediment bed within the Site is separated into two distinct types:

- Cohesive (i.e., muddy bed composed of a mixture of clay, silt, sand and organic matter)
- Non-cohesive (i.e., sandy bed composed of sand and gravel, with small amounts of clay and silt)

Sediment samples indicate that the bed is primarily composed of cohesive sediment, with non-cohesive sediment occurring in isolated, localized areas at the Site. For similarly-sized materials, cohesive sediments are typically more resistant to erosion than non-cohesive sediments. Erosion rate data of sediment collected at the Site indicate that sediments downstream of approximately PB-040 tend to have significantly less erodibility with increasing depth in the bed due to consolidation; sediments upstream of approximately PB-040 tend to exhibit variable erodibility in the vertical direction. A description of the erosion rate parameters and analysis can be found in Appendix B of the STM Report (Anchor QEA 2011c). The primary sources of sediment to the Site are loading from main inflow, the East Fork Tributary, and direct runoff.

The stability of the sediment bed is an important factor for considering natural recovery processes and to evaluate remedial alternatives for sediments that might exceed the identified RALs (discussed in Section 3.2) for the Site. The results of the STM analyses were used to develop the following conceptual model for sediment transport at the Site:

- The Site is a net depositional area over annual time scales, with approximately 55 to 60 percent of the sediment load entering the Site from the surrounding watershed being deposited within the Site.
- Net sedimentation rates (NSR) are spatially variable, with values ranging from less than 0.1 centimeters/year (cm/year) to more than 2 cm/year.
- Bed erosion is typically an episodic process that is most pronounced during high-flow events. During the 100-year high-flow event (i.e., event with one percent chance of occurring in a given year), net erosion occurs in approximately 65 percent of the total bed area and the majority of the net erosion is less than 6 cm. During the two year high-flow event (i.e., event with 50 percent chance of occurring in a given year), net erosion occurs in about 45 percent of the total bed area and erosion depths are less than 2 cm. Generally, erosion at the Site, even during low frequency, high-flow events, only affects surface-layer sediments and is limited to bed depths that represent

relatively recent deposition.

- Results from natural recovery modeling based on simulation of sediment transport processes indicate that for about 70 percent of the Site, the chemical concentrations in the mixing-zone layer (top 10 cm of sediment; Anchor QEA 2009) will decrease by one-half of their current concentrations in less than 10 years, assuming "clean" sediment input (Anchor QEA 2011c). Note that this estimation assumes an average chemical concentration over the entire 10 cm thickness of sediments and does not discretize concentrations within individual (e.g. shallower) layers. Future evaluations will consider PCB concentrations in discrete depth zones to better evaluate MNR in critical horizons.

2.5.5 Upstream Stormwater Detention Basin

To improve the floodplain storage volume in the Patrick Bayou system, the City of Deer Park and the Harris County Flood Control District jointly purchased approximately 35 acres of undeveloped property located south of SH 225, west of East Boulevard and east of Deer Park Gardens Section Two (upstream of the Site), to construct a stormwater detention basin.

The detention basin is intended to alleviate flooding on Patrick Bayou during a significant rain event (i.e., 100-year storm event). The basin creates a backwater condition to direct higher stage flows into the detention basin rather than continue down the channel, but allows the lower stage flows to pass through a 6-foot-by-5-foot box culvert. As the basin fills, the head across the weir gets smaller until it is equal to the channel. In this case, the basin is full after the peak of the hydrograph has passed. As the surface water elevation in Patrick Bayou recedes following the high flow event, water will flow out of the detention basin and back into the channel across the weir.

The detention basin is expected to reduce the peak flow rate into Patrick Bayou during the 100-year flood by about 10 percent. In addition, the detention basin would only affect flow into Patrick Bayou during floods with return periods of about 10 years or greater. For floods with return periods of 10 years or more, the reduced inflow rates to Patrick Bayou (i.e., 10 percent decrease for 100-year flood) would produce lower current velocities than present conditions and, thus, less sediment bed erosion. It is anticipated that the proposed detention basin would have a minor effect on sediment loads to Patrick Bayou, which would correspond to relatively minor changes in long-term sedimentation rates in the Bayou. Refinement of the STM is anticipated to account for this change in the pre-design phase of the project, if warranted.

Appendix A provides additional discussion regarding the upstream stormwater detention basin and how the basin was evaluated in the chemical fate and transport modeling.

2.6 Nature and Extent of Contamination

2.6.1 Contaminant Sources

During the RI, extensive effort was expended to evaluated numerous potential sources of contamination to the Site, including point sources, groundwater, spills, bank erosion, atmospheric deposition, and interaction with the HSC. In general, the RI findings are consistent with the conceptual site model (CSM) of legacy contamination, and no ongoing sources of contamination to sediments were identified.

Four outfalls currently discharge just upstream of the Site: City of Deer Park WWTP outfall, Lubrizol outfall 001, and two stormwater only outfalls (Lubrizol outfalls 002 and 006). Three other outfalls currently discharge directly into the East Fork Tributary: Praxair outfall 001, Rohm and Haas outfall 003 (stormwater), and Lubrizol outfall 007 (stormwater). Within the concrete-lined channel, seven outfalls currently discharge stormwater, treated domestic wastewater, and/or utility wastewater. Downstream of the concrete-lined channel, six outfalls (four Shell and two Oxy) currently discharge stormwater, non-process wastewater, fire water, and/or non-contact cooling water withdrawn from the HSC. Currently, there are no known active point-source discharges that add contaminants to the Site above National Pollutant Discharge Elimination System (NPDES) discharge limits or above typical urban background loading. Thus, current direct discharge to the Site from permitted outfalls is not considered a substantive source of contaminants to the Site. Outfalls are shown on Figure 2-2.

Currently, groundwater from each facility has very little measurable interaction with the Site and does not contribute to chemicals of potential concern (COPCs) observed in Site sediments and surface water, as discussed in the RI Report (Anchor QEA 2013b). Historically, contaminated groundwater may have entered the Site via discharge through sediments or bank seeps. While deeper groundwater bearing zones (i.e., below the Beaumont Formation) are not hydraulically connected to the Site, shallow groundwater bearing zones have some connection to the Site. Releases of chemicals to upland soils may have resulted in migration of these chemicals to groundwater, which subsequently migrated to the Site.

There is no historical record of spills prior to 1958. Historical spills are potential sources of chemicals at the Site. A review of spill reports maintained by the Texas Parks and Wildlife Department from 1958 to 2005 (Denton 2006) revealed no documented spills at the Site during that time. Numerous spills have occurred in the HSC adjacent to the Site. Spills in the HSC could potentially travel via surface water into the Site.

Potentially, soils or fill containing chemicals could erode from unprotected banks of the Site and enter surface water or sediments. However, much of the shoreline has been modified by placement of fill and/or concrete armor over time. The sources and quality of the fill materials is unknown. Currently, much of the Site banks are covered with bank stabilization materials, which inhibit erosion. Unstabilized areas generally have natural cover as well, to inhibit erosion; there are few, if any, significant areas of bare soil adjacent to the Site. Thus, there are no known current sources of contaminants loading associated with bank erosion for the Site.

Nearly all surface water bodies are exposed to potential deposition of chemicals in the atmosphere. Chemicals deposited to surface waters of the Site may come from local and regional point and non-point sources. Chemicals deposited to surface water may become dissolved in surface water, adsorbed to particulates in surface water, or may adsorb to sediments. Polycyclic aromatic hydrocarbons (PAHs), PCBs, mercury, and polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDDs/PCDFs) are common atmospheric pollutants in urbanized environments and are expected to represent both current and ongoing sources of contamination to the Site, although at very low levels.

The HSC is known to be impacted from sources other than the Site by several contaminants, including PAHs, PCBs, PCDDs/PCDFs, pesticides, and mercury. The Site is tidally influenced and the tidal fluctuation produces an exchange of surface water between Patrick Bayou and HSC within the Site. Chemicals released, historically and currently, into the HSC may migrate into the Site as a result.

2.6.2 Distribution of Indicator Chemicals

The RI Report (Anchor QEA 2013b) identified four indicator chemicals (ICs) that were the basis for the nature and extent evaluation. PCBs were selected as the primary IC for the RI based on potential risk to wildlife and benthic invertebrates (benthos). PAHs, lead, and bis(2-ethylhexyl)phthalate (BEHP) were selected as secondary ICs based on some potential risk to benthos. The ICs selected in the RI Report were media-specific and were based on the results of the BERA (Anchor QEA 2012, 2013a) and to a lesser extent on non risk-based factors. ICs and their rationale for selection for each media are discussed in the RI (Anchor QEA 2013b). The following sections summarize the nature and extent of ICs in Site media presented in the RI.

2.6.2.1 Surface Sediment

Surface sediment samples from 66 locations within in Site were collected representing the entire interval from the surface up to a depth of 11 cm below the surface during the RI[4]. Samples from 14 stations were collected in 2006, 46 stations in 2009, and six stations in 2011. All four ICs were included in 2006 and 2009 sediment sample analyses. The 2011 samples were analyzed for PCB Aroclors and PAHs because those are the primary ICs in the upstream area that was the focus of that investigation. Results for surface sediment ICs are mapped in Figures 2-4 through 2-7 (PCBs, PAHs, BEHP, and lead, respectively). In general, some of the highest concentrations of PCBs, PAHs, BEHP, and lead were reported at Stations PB-032, PB-036, PB-053A, and PB-081. The maximum total PCB congener value was reported at Station PB-026. Maximum concentrations of both PAHs and lead were reported at Station PB-081 and the maximum concentration for BEHP was reported at Station PB-036.

[4] Several samples have been collected during the RI at shallower intervals (e.g., 0 to 2 cm). Results from these shallow surface intervals are not discussed here. Results for these shallow intervals can be found in Anchor (2007).

In addition, several surface sediment samples were collected upstream of the Site boundary. Sample locations are shown in Figure 2-8 and analyzed for PCBs, PAHs, and lead. In general, upstream concentrations of ICs are less than or within the range of values observed in Site surface sediments. To the extent that upstream concentrations of ICs are similar to those in certain areas of the Site, this will limit the reduction in concentration that can be achieved in these areas through natural recovery.

2.6.2.2 Subsurface Sediment

Subsurface samples, defined as samples collected from depth intervals greater than 11 cm, were collected at 12 locations (Figure 2-9). All samples were analyzed for all sediment ICs. The distribution of total PCBs[5], total PAHs, BEHP, and lead are shown in Figures 2-10 through Figure 2-13. In general, ICs show increasing concentration with depth; with subsurface maximum concentrations between 50 and 120 cm below mudline. The stations exhibiting the highest subsurface concentrations of total PCBs, total PAHs, and lead were PB-057, PB-048, and PB-042. With few exceptions, the lowest concentrations of ICs are observed in sample intervals near the contact with the native regional clay formation (i.e., Beaumont Formation).

The vertical profiles of PCBs and other COPCs in Patrick Bayou show changes at the Site in terms of ongoing reduction of surface sediment concentrations. The vertical profiles of other COPCs, including PAHs and BEHP, show that the concentrations of these COPCs at the surface and available to potential surface receptors have also significantly declined over time, since the peak of contaminant loading (Anchor 2007). Although the peak concentration varies by COPCs and location, the vertical profiling and associated radiometric analyses conducted in 2006 indicate that most loading for these COPCs occurred more than 30 years ago (92 cm and deeper; Anchor 2007). These observations indicate historical or legacy discharges are responsible for the bulk of the COPCs (especially PCBs) observed at the Site and that natural attenuation of COPCs should continue at the Site to lower potential risk to surface receptors.

[5] Only PCB Aroclors were analyzed in subsurface sediments.

2.6.2.3 Porewater

During the RI, porewater was collected from ten locations within the Site boundary. Figures 2-14, 2-15, and 2-16 present the results for total PCB congeners, total PAHs, and BEHP by location, respectively. Lead was not detected in any of the porewater samples. Station PB-036 had the highest concentration of all three detected ICs while PB-006A had the lowest concentration of all three detected ICs. Porewater concentrations provided site-specific information on chemical partitioning within the sediments (see Appendix A).

2.6.2.4 Surface Water

PCBs were the only IC identified for surface water in the RI because they were the only chemical of interest to exceed risk-based screening levels in the BHHRA or BERA (Anchor QEA 2013b). Surface water was collected during three sampling events (Figure 2-17). Twenty-two samples were collected from eight stations from outside and within the Site boundary in 2009. These surface water samples were analyzed for several target analytes. In 2011 four samples were collected from within the Site boundary, between Stations PB-070 and PB-101. In 2014, a total of 23 samples were collected from 21 stations located both outside and within the Site boundary (Appendix D). In 2011 and 2014, PCBs were the only COC[6] included in the surface water sample chemical analysis.

Total PCBs were detected in all samples for the 2009, 2011, and 2014 sampling events (Figure 2-18). For the 2009 sampling event, the highest concentration of total PCBs (0.431 µg/L) was reported at Station PB-059A. For the 2011 sampling event, the highest concentration of total PCB congeners was reported at Station PB-080 (0.143 µg/L), and the farthest upstream station, Station PB-101C, had the lowest total PCB congener concentration (0.00565 µg/L). The highest concentration of total PCB congeners reported during the 2014 sampling event was from the sample collected at Station PB-070B (0.072 µg/L), and the farthest upstream station, Station PB-119B, had the lowest total PCB congener concentration (0.000566 µg/L). As shown on Figure 2-18, in general, surface water concentrations of PCBs have declined significantly over time.

[6] Not including conventional analytes such as organic carbon, total suspended solids, etc.

2.6.2.5 Tissue

Hazard quotients (HQ) above one (1.0) were calculated in the BERA (Anchor QEA 2013c) for piscivorous (HQ = 1.7) and shorebird populations (HQ = 1.0) due to PCBs in potential prey tissue. No COCs were identified in the BHHRA (Anchor QEA 2012). Therefore, the nature and extent summary below is limited to whole body tissue data used in the BERA and focuses on PCBs expressed as 2,3,7,8-TCDD toxic equivalents (TEQs) using avian (TEQ_{avian}) toxic equivalency factors (TEFs). A full discussion of all biota data can be found in the RI.

A total of 83 whole body tissue samples from locations within the Site were analyzed as part of the BERA investigation. These included 33 shellfish samples and 50 fish samples. Four different shellfish species were collected and analyzed. These included blue crab, brown shrimp, oyster, and white shrimp. Shellfish were analyzed in two different size classes. Five different fish species were collected and analyzed. These included Gulf killifish, Gulf menhaden, pinfish, sand seatrout, and striped mullet.

For shellfish, the highest PCB TEQ for avian predators was reported in blue crab samples (782.9 [TEQ_{avian}] ng/kg). The average concentration in blue crab samples was 380 TEQ_{avian} ng/kg. Spatial representation for shellfish PCB TEQ_{avian} results are depicted in scatterplots and maps on Figure 2-19. In general, the highest total PCB TEQ_{avian} values for shellfish were observed between 2,000 and 8,000 feet from the HSC (i.e., PB-020 to PB-080).

In whole body fish tissue, the concentration of PCB TEQ_{avian} values ranged between 77.5 TEQ_{avian} ng/kg and 1,173 TEQ_{avian} ng/kg. The highest PCB TEQ_{avian} value was reported in Gulf killifish samples (1,173 [TEQ_{avian}] ng/kg). To depict potential spatial relationships of concentrations along the Site PCB TEQ_{avian} results were graphed with scatterplots showing results values versus distance from the mouth of the Site at its confluence with the HSC. For Gulf killifish, as shown in Figure 2-20, a general cluster of higher PCB TEQ_{avian} values is apparent near stations PB-050 to PB-070 as opposed to either the mouth or the upstream end of the Site. Spatial representation for menhaden PCB TEQ_{avian} results is depicted in Figure 2-21. In contrast to Gulf killifish, a general trend of increasing concentration is apparent from the mouth of the Site to station PB-058. Spatial representation for pinfish, sand seatrout, and striped mullet PCB TEQ_{avian} results, is depicted in Figure 2-22. The data in these figures show a slight trend of increasing concentrations of PCB result values and TEQs is visible from the mouth of the Site toward the upstream portions of the Site.

2.6.2.6 Mean Probable Effects Level Quotient

During the development of the BERA, several different quotient or toxic unit models that have been described in the scientific literature to predict potential sediment toxicity based on bulk sediment chemistry were evaluated. The performance of each model was assessed by applying it to Site-specific, co-located bulk sediment chemistry data and bioassay (i.e., toxicity) data for the Site. Of the models assessed, a mean quotient model using the Probable Effects Level (Long et al. 2006) was initially selected based on several performance criteria identified in the BERA Work Plan. This model, referred to as the mean Probable Effects Level-Quotient (PEL-Q), was refined using a series of optimization steps developed in the approved BERA. This optimized model included four COPCs (total PCBs, total PAHs, lead, and BEHP) that demonstrated a statistically significant difference in concentration between toxic and nontoxic samples. Of the four COPCs, total PCBs presented the dominant contribution to the calculated mean PEL-Q (Anchor QEA 2013c). However, during development of the BERA, it became apparent that the toxicity model had several limitations that could not be resolved and that led to a significant amount of uncertainty in its utility and relevance as a primary LOE. Consequently, this mean PEL-Q metric was then used as one of three lines of evidence (LOEs) within a weight-of-evidence (WOE) framework in the BERA to characterize risk to the benthic community. Uncertainties of the toxicity model notwithstanding, to attempt to quantify the nature and extent of surface sediment conditions with respect to the four ICs, the PEL-Q metric has been utilized herein to develop a paired relationship between sediment chemistry and apparent toxicity.

Surface bulk sediment samples collected during the RI were used to describe the nature and extent of the distribution of sediment ICs using the mean PEL-Q. All RI surface sediment samples that included all four ICs were included in the dataset. Surface sediment samples from 66 locations within the Site were collected from 0 to up to 11 cm during the RI. Samples from 14 stations were collected in 2006, 46 stations in 2009, and six stations in 2011. All four ICs were included in 2006 and 2009 sediment sample analyses. The 2011 sampling event included only PCBs and PAHs; thus, a mean PEL-Q was not calculated for those locations. As a result, a total of 60 locations were included in the calculation of Mean PEL-Q. Surface sediment mean PEL-Q values are mapped in Figure 2-23. In general, the highest mean PEL-Q values were reported at Stations PB-026, PB-032 and PB-053A. The maximum mean PEL-Q value, 166.5, was reported at Station PB-026.

2.6.3 Chemical Characteristics of Indicator Chemicals

The degree to which the ICs move from sediment to water and become bioavailable is affected by their solubility in water, their tendency to adsorb to sediment particles, and the rate at which they degrade in the environment. The parameters used to characterize these properties are the water solubility, partition coefficient, and biodegradation rate of each chemical. The primary ICs for the Site (PCBs) and the secondary ICs do not volatilize to a significant degree, so properties related to volatilization (primarily Henry's Law constant) are not discussed further. Low molecular weight PAHs (e.g., naphthalene) and BEHP are more volatile in some environmental settings, and volatilization will be considered for these ICs if they are present to a significant degree. Table 2-1 presents a summary of the chemical properties for the ICs.

ICs with lower water solubility and higher partition coefficients have less potential to enter the aqueous phase and become mobile. ICs that are strongly adsorbed to the sediment may be transported with sediment if the sediment is resuspended by high surface water velocities and can also be exchanged between sediment porewater and surface water. The following subsections describe the relevant chemical properties of the ICs.

2.6.3.1 Polychlorinated Biphenyls

In general, PCBs are less soluble in water and adsorb more strongly to sediment than the other ICs. Although these properties make PCBs less bioavailable than the other ICs, PCBs tend to bioaccumulate (PCBs that enter an organism tend to be stored rather than broken down or excreted), which can increase the potential effect of PCBs on the food chain. Chemical properties are more difficult to define for groups of chemicals, such as PCBs, than for individual constituents. In general, less chlorinated PCBs are more water soluble and adsorb less strongly to sediment than the more chlorinated PCBs. This tendency is illustrated by the relatively low solubility and high partition coefficient, in sequence, for the deca-substituted (PCB-209) and tetra-substituted homologs as compared to the tri-substituted homologs (Table 2-1). The heaviest PCB, PCB-209 (decachlorobiphenyl) is even less water soluble and partitions more strongly to sediment than the tetra-substituted PCBs. The lighter PCBs also tend to be more biodegradable under aerobic conditions. Anaerobic biodegradation has also been reported in some cases, although anaerobic degradation tends to focus on the heavier PCBs. Reductive dechlorination by aerobic or anaerobic organisms tends to focus on the meta- and para-chlorines. Ortho-substituted PCBs are less likely to be biodegraded but these PCBs are also less toxic than the coplanar PCBs (Field et al. 2007). The very large majority of sediments at the Site are anaerobic, and degradation of PCBs is typically quite slow under those conditions to the point that degradation of PCBs in sediments is generally not considered an important process on the timescales of interest for the RI/FS. Additional information on Site-specific PCB characteristics is included in the chemical fate modeling documented in Appendix A.

2.6.3.2 Total Polycyclic Aromatic Hydrocarbons

As with the group of PCBs, PAHs, as a group, are complex to evaluate and the data presented in Table 2-1 indicate a wide range of chemical properties. Certain PAHs (e.g., acenaphthene and naphthalene) are more likely to be present in the aqueous phase than other PAHs because they have higher solubility in water and lower partition coefficients. However, acenaphthene and naphthalene, in particular, have relatively short half-lives in aerobic conditions, which may prevail in shallow surface water. Other PAHs (e.g., benzo(k) fluoranthene and indeno(1,2,3-cd)pyrene) have significantly less solubility in water and higher partitioning coefficients. These ICs are less likely to be present in the aqueous phase and have relatively long half-lives under anaerobic conditions that are present in sediment at the Site.

Generally, PAHs are more soluble than heavier PCBs (e.g., PCB-209) and less soluble than BEHP. Despite having a greater solubility than heavier PCBs, PAHs are less bioaccumulative because they are metabolized by organisms. Certain PAHs (e.g., anthracene, fluoranthene, and pyrene) demonstrate similar solubility and bioavailability as lighter PCBs (e.g., tri- and tetra- substituted PCBs), while naphthalene and acenaphthene are approximately an order of magnitude more soluble than tri-substituted PCBs.

2.6.3.3 *Bis(2-ethylhexyl) Phthalate*

Data presented in Table 2-1 indicate the solubility and partitioning coefficient of BEHP is similar to tri-substituted PCBs. Biodegradation of BEHP has been reported with a half-life range of 41 to 389 days in anaerobic conditions, which are likely in subsurface sediment at the Site (USEPA 1996). Aqueous BEHP is also relatively biodegradable within the aerobic conditions likely present in the shallow surface water of the Site. The aerobic half-life of BEHP is between 5 and 23 days (USEPA 1996; Table 2-1).

2.6.3.4 *Lead*

The solubility of metals, including lead, is highly dependent on water chemistry, which affects the speciation of the metal. Lead is reported as insoluble in water at neutral and higher pH (USEPA 2007). Lead can react with a variety of negative radicals (such as sulfide, sulfate, and carbonate) to form insoluble salts.

Analytical tests performed on samples from the Site provide multiple lines of evidence that the lead found at the Site may not be bioavailable:

- The acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) analyses test whether the amount of sulfide radicals present in the environment is sufficient to sequester the available divalent metals, such as mercury and lead. When the molarity of AVS exceeds the molarity of SEM, the SEM are present in the form of insoluble sulfide salts that are not bioavailable (USEPA 2000). The AVS/SEM analyses summarized by Anchor QEA (2010) demonstrate that sufficient sulfide is present at the Site to sequester all of the available lead as insoluble sulfide minerals.
- Lead was not detected in porewater (Anchor 2008).

Tissue samples were not analyzed for lead as it was not identified as a COPC for fish or wildlife. Lead was excluded as a COPC based on simple bioaccumulation modeling of bulk sediment data using biota-sediment accumulation factors, which did not result in predicted tissue concentrations above a risk-based screening level (Anchor 2008).

2.7 Contaminant Fate and Transport

As discussed above and in greater detail in Section 4 of the RI, the primary IC class at the Site is PCBs. Total PAHs, BEHP, and lead are also associated with some risk to benthic receptors and are secondary ICs. The fate and transport of PCBs and the secondary ICs is a function of their chemical properties and the physical conditions of the Site. This section discusses, key fate and transport processes, and the modeling framework used to evaluate the fate and transport of ICs at the Site in this FS (which is presented in Appendix A).

There are a number of processes that can affect fate and transport of sorptive chemicals (such as PCBs) within an aquatic system (Figure 2-24). The most significant chemical fate and transport processes affecting concentrations of PCBs (and similar sorptive compounds) within Patrick Bayou include:

- Sediment-water interactions – Because of the hydrophobic nature of PCBs, they preferentially bind to particulate matter. As discussed above, the extent of hydrophobicity varies by congener, with the lighter, less chlorinated congeners exhibiting less hydrophobicity than the heavier, more chlorinated congeners. The sediment bed, therefore, serves as a net sink, adsorbing PCBs. To the extent that PCBs may have accumulated within the bed over time (e.g., if there were historical releases and subsequent transport), they can act as a source to the water column, and chemicals being transported in the water column can likewise deposit on the bed. The flux of sediment particles (and particle-bound PCBs) between the bed and water column are driven by sediment deposition and erosion processes, especially during episodic events such as floods. Deposition also provides a mechanism for natural recovery if concentrations of PCBs on particles in the water column are lower than those at the bed surface. Thus, within-bed dynamics such as transfers between surface and deeper layers of the bed are also important.
- Partitioning and dissolved phase flux – The distribution of PCBs between the particulate and dissolved phases within the water column and bed sediments are determined by their partitioning behavior (as quantified by the partitioning coefficient). Because they are hydrophobic (as indicated by relatively high K_{OC}; Mackay et al. 1992), PCBs will primarily be present in particulate form, which means that their fate is largely determined by sediment transport processes. However, in

areas where PCBs have accumulated within the surface layer of the sediment bed, partitioning will result in porewater concentrations that can be much greater than those in the overlying water column. Such a concentration gradient, through the process of surface exchange flux (due to diffusion, bioturbation, and tidal pumping), results in a transfer of dissolved-phase mass to the water column that can affect concentrations in the Site under low flow conditions.

- Transport in the water column – PCBs that are present in the water column (in both dissolved and particulate phases) are transported with the currents, which are affected by freshwater flow in addition to more complex circulation patterns associated with tides and ship traffic. Transport in the water column differs depending on the flow regime, since the relative importance of freshwater flow and tidal action, as well as the fate and transport processes that are active, differ by flow conditions. For example, under higher flow conditions, transport associated with sediment deposition and erosion is much greater.
- External sources – In addition to fluxes from the sediment bed, which are considered an internal source, PCBs also enter the aquatic environment within the Site via external sources. As discussed in Section 2.6.1, transport of ICs via groundwater to the Site may have occurred historically but are no longer ongoing to the Site. PCBs were detected in surface water samples collected upstream of the Site, as well as in the East Fork, albeit at relatively low concentrations. Furthermore, PCBs were detected in the HSC upstream of the Site and in dry and wet atmospheric deposition samples that were collected adjacent to the Site as part of the TMDL study (Rifai and Palacheck, 2006, 2007, 2008, 2009, 2010). These processes therefore represent external sources to the aquatic environment of the Site.

Water column data collected during and subsequent to the RI provide a considerable amount of insight regarding PCB fate and transport processes within Patrick Bayou. Figure 2-18 shows spatial profiles of water column PCB data collected during 2009, 2011 (blue and red circles), and 2014 (green circles). These datasets show an increase in water column PCB concentration occurring across the concrete-lined channel (the upstream and downstream ends of the concrete-lined channel are indicated by vertical dashed lines on the figure). In 2009 and 2011 dataset total PCB concentrations increased from approximately 5 nanograms per liter (ng/L) to nearly 100 ng/L across this relatively short reach, followed by a more gradual increase across the remainder of the Site. These data indicate that a significant load of PCBs to the water column begins at this location.

Additional water column data were collected in 2014 (green circles on Figure 2-18) at a higher spatial resolution in the concrete-lined channel to develop a better understanding of the nature and extent of PCBs in surface water over this reach. These results confirmed the understanding of the spatial distribution of PCB loading Site-wide, and further demonstrated that a significant load is occurring over a relatively small portion near the down-stream end of the concrete-lined channel (from approximately PB-082 to PB-075).

Water column concentration increases downstream of the concrete-lined channel are likely a result of dissolved-phase flux of PCBs from PCB-containing sediments to the overlying water column. The subsequent decrease in these data at the downstream end of the Site is likely due to tidal mixing and dilution with water entering the Bayou from the HSC.

Figure 2-18 also shows that concentrations measured in 2014 were much lower than those measured in 2009 and 2011 which suggests that natural recovery is active at the Site. Further discussion of these trends with respect to natural recovery is provided in Section 4.3.2 and Appendix E.

A comprehensive chemical fate and transport model was developed to support this FS. This model, which was developed and calibrated to reproduce the observed longitudinal gradients in water column PCB concentrations described above, is described in detail in Appendix A. A brief summary of the overall model objectives and framework is provided below.

2.7.1 Fate and Transport Modeling

The primary goal of the chemical fate and transport modeling study (summarized in Appendix A) is to simulate physical and chemical processes that are controlling the chemical fate and transport of PCBs within Patrick Bayou. Specifically, the primary objective of the modeling was to develop a mathematical framework that can: 1) build upon the existing hydrodynamic model and STM for the Site that are described in the STM Report (Anchor QEA 2011c); 2) provide a quantitative linkage between PCBs in sediments and PCBs in surface water (i.e., predict observed mass flux); and 3) be used as a predictive management tool to evaluate the effectiveness of various remedial alternatives, including natural recovery, in meeting the relevant water quality standard, and providing improvements to potential benthic risk issues.

The mathematical modeling framework that was applied consists of three models that were linked together: hydrodynamic, sediment transport, and chemical fate and transport (Figure 2-25). The hydrodynamic model and STM are documented in the STM Report (Anchor QEA 2011c), while the chemical fate model is documented in Appendix A. These models were developed and calibrated, and together form a quantitative framework that can be used as a management tool to guide risk management decisions for the Site. The calibration and validation of the model framework indicates that it can simulate hydrodynamics, sediment transport, and chemical fate and transport within Patrick Bayou with sufficient accuracy to support its use in making relative comparisons among remedial alternatives in the FS Report. Because of the uncertainties associated with modeling due to data limitations, model sensitivity analyses were conducted to develop uncertainty bounds around its predictions. These uncertainty bounds were carried through the simulations of remedial alternatives presented in Appendix A.

3 BASIS FOR REMEDIAL ACTION

3.1 Remedial Action Objectives

RAOs for the Site were developed in discussions with USEPA coincident with the preparation of the RI. The RAOs are:

- Evaluate and address risk to benthos associated with PCBs, PAHs, lead, and BEHP.
- Mitigate risk to aquatic-dependent wildlife associated with PCBs.
- Reduce PCB concentrations in surface water to the saltwater chronic criterion, 30 ng/L, in the Texas Surface Water Quality Standards (TSWQS).

The surface water RAO was developed in part to address an applicable or relevant and appropriate requirement (ARAR) for the State of Texas. Detailed discussion of ARARs, including water quality ARARs, is provided subsequently in this Section.

3.2 Benthic Risk RAO: Preliminary Remediation Goals

To address the benthic risk RAO, a preliminary remediation goal (PRG) was developed for this FS based on the BERA. More specifically, the PRG was derived from site-specific, paired sediment chemistry and sediment toxicity data (referenced above in section 2.6.2.6.) that were used to characterize risk to the benthic community in the BERA. Using the sediment toxicity and sediment chemistry LOEs approved in the BERA, a threshold mean PEL-Q was identified that represents a sediment PRG consistent with the narrative intent of the benthic risk RAO. The development of the benthic risk PRG is presented in the following subsections.

3.2.1 Summary of the BERA Risk Characterization

As stated previously, WOE approach was developed to assess benthic risk in the BERA. This WOE approach included the review and analysis of site-specific bulk sediment chemistry data, sediment bioassay (toxicity) data, and benthic community data as LOEs. The objective of the WOE approach was to use the apparent correspondence between the values or metrics assigned to the LOEs, and the overall strength of the correspondence, where it existed, to identify areas of the Site where measurable incremental risks to the benthic community due to exposure to site-related COPCs are deemed probable, indeterminate, or low.

Twelve different locations within the Site with co-located synoptic bulk sediment chemistry, bioassay, and benthic community data were included in the analysis. Based on the WOE approach, three of these locations were identified as areas where incremental Site-related risks to the benthic community was probable, four areas were identified as indeterminate, and five areas were identified as low (Figure 8-1 of the BERA, Anchor QEA 2011b).

Although the BERA did not identify any specific risk management recommendations for benthic risk, the RI concluded that remedial alternatives should be evaluated in the FS that lower the overall Site and sub-area risk for areas that are characterized as indeterminate and probable risks to benthos. The RI also recommended that risk management strategies for benthic receptors should be considered within the overall context of other risk management considerations, such as surface water quality standards.

To support the remedial alternatives evaluation, the results of the BERA benthic risk assessment were used to identify a mean PEL-Q threshold, the definition of which was discussed in Section 2.6.2.3, that would represent the lowest threshold associated with indeterminate sediment risk as defined in the BERA, based on the sediment toxicity LOE. The benthic community LOE was not incorporated in this analysis given the very low degree of correspondence between this LOE and the sediment toxicity and chemistry LOEs.

In the BERA, the sediment toxicity LOE was evaluated using the frequency of toxicity associated with a particular location. To characterize toxicity for a specific location, the proportion of toxic samples was determined for each location. The proportion toxic was calculated as follows:

$$\text{Proportion toxic} = \text{Toxic results/Total results}$$

Next, overall incremental risk to benthos due to sediment toxicity was categorized for each location using the proportion of toxic samples according to the following criteria:

- Probable Risk – the proportion of toxic samples was equal to or exceeded 50 percent
- Indeterminate Risk – the proportion of toxic samples was between 25 and 50 percent (exclusive)
- Low Risk – the proportion of toxic samples was less than or equal to 25 percent

3.2.2 Identification of PRG for Benthic Risk

To identify a PRG for benthic risk, the lowest mean PEL-Q threshold above which indeterminate or probable risks were observed based on the sediment toxicity LOE was identified using the BERA analysis. The mean PEL-Q and proportion of toxic samples at each sample location evaluated in the BERA is presented in Table 3-1. Based on the data set presented in the BERA, the lowest mean PEL-Q and toxicity threshold associated with indeterminate sediment toxicity is 7.56. Thus, a mean PEL-Q threshold of 7.56 was identified as the benthic risk PRG to evaluate remedial alternatives against the benthic risk RAO for the FS. Figure 2-23 presents mean PEL-Q and toxicity results for surface samples collected during the RI, as described in Section 2.6.4. Figure 3-1 presents Thiessen polygons where the benthic risk PRG is exceeded based on the 2009 RI surface sediment dataset. This figure does not consider changes in sediment chemistry/mean PEL-Q that might have occurred due to natural recovery since the baseline sediment dataset was collected in 2009. Note that it is anticipated that this model will be updated using new baseline data in the pre-design phase of this project.

3.3 Aquatic-dependent Wildlife RAO: Preliminary Remediation Goals

Potential risks to aquatic-dependent wildlife were identified for two receptors, spotted sandpiper and belted kingfisher, due to exposure to PCBs in their diet and through incidental sediment ingestion. For the spotted sandpiper, the PCB HQ was equal to 1.0, and for the belted kingfisher, the PCB HQ was equal to 1.7. Although these risk levels are at or exceed the threshold HQ of 1.0, these exceedances do not require the derivation of aquatic-dependent wildlife-specific PRGs that are separate from the surface water and benthic PRGs defined in the preceding two sections. This is because the surface water and benthic PRGs directly address PCBs in surface water and sediment, which are the primary exposure pathways that contribute to PCB bioaccumulation in the tissue of food items consumed by these two receptors. Reductions in surface water PCB concentrations and reductions in the bioavailability of sediment-based PCBs will result in a reduction of PCB concentrations in food items consumed by the sandpiper and the kingfisher to levels that are protective of these receptors. Specifically, due to the linkage between site surface water and sediment concentrations of PCBs and the concentration of PCBs in site prey items consumed by the spotted sandpiper and the belted kingfisher, reductions in PCBs concentrations in surface water and sediment on the order of 40 percent should be sufficient to reduce the highest HQ from 1.7 to 1.0 or less. As discussed in Appendix A, surface water concentrations have already dropped by a factor of two to three times from 2009 to 2014, and are expected to decrease further in the future. Sediment concentrations decrease by similar or greater amounts depending on location. These actual and modeled reductions are sufficient to reduce levels in prey items that are protective of these avian receptors.

3.4 Applicable or Relevant and Appropriate Requirements

The development and evaluation of remedial alternatives, as presented in Sections 4 and 5 of this document, includes an assessment of the ability of the remedial alternatives to address Applicable or Relevant and Appropriate Requirements (ARARs) of environmental laws and other standards or guidance (including potential local regulations) to be considered (TBC) as part of the selection of the remedy. Table 3-2 provides a broad summary of potential ARARs and TBCs that have been identified for this Site. Many of the ARARs and TBCs in Table 3-2 are relevant to only some of the remedial alternatives, but all of the requirements that may be relevant to the Site and any of the remedial alternatives are identified in the list.

After a remedy is selected, a detailed review of ARARs specific to the selected remedial action would be conducted and included in the Design Analysis Report for the selected action. The implementation of the remedy generally would not require Federal, State or local permits because of the permit equivalency of the CERCLA remedy-selection process (40 CFR 300.400(e)(i)), but remedial actions would be completed in conformance with substantive technical requirements of those regulations that have been determined to be ARARs.

The ARARs in Table 3-2 can be divided into three categories, although some ARARs may belong to more than one of these categories:

- Chemical-specific requirements
- Location-specific requirements
- Performance, design, or other action-specific requirements

Chemical-specific ARARs are typically the environmental laws or standards that result in establishment of health- or risk-based numerical values. When more than one of these chemical-specific ARARs are applicable to site-specific conditions, a remedial alternative should generally comply with the most stringent or conservative ARAR. Chemical specific ARARs presented in Table 3-2 include Clean Water Act (CWA) criteria and State water quality and waste standards. The identification of action areas to address PCBs in sediment is based on attaining the surface water quality standard, a chemical-specific ARAR.

Location-specific ARARs include restrictions placed on the implementation of certain types of activities based on the location of a site. Some examples of specific locations where restrictions may be considered include floodplains, wetlands, historic places, certain land use zones, and other sensitive habitats. Location-specific ARARs presented in Table 3-2 include the Rivers and Harbors Act, Coastal Zone Management Act, and Federal Emergency Management Agency/National Flood Insurance Program regulations.

The action-specific ARARs are generally technology or activity-based limitations or guidelines for management of pollutants, contaminants, or hazardous wastes. These ARARs are triggered by the type of remedial activity selected to achieve the RAO, and these requirements may indicate how the potential alternative must be achieved. Action-specific ARARs presented in Table 3-2 include water quality certifications (CWA Section 401) and discharges of dredged and fill material (CWA Section 404), Clean Air Act, Endangered Species Act (ESA) and other wildlife protection acts.

The following sections discuss ARARs that have the most significance to the evaluation of remedial alternatives for the Site. Action-specific ARARs do not apply to all of the remedial alternatives. For example, requirements for waste management and hazardous materials transportation are most significant for remedial alternatives that involve removal of sediment, and would not apply at all to remedial alternatives that involve no removal of material from the Site. The types of actions that trigger compliance with these requirements are also discussed.

3.4.1 Water Quality and Water Resources

3.4.1.1 Section 303 and 304 of the Clean Water Act and Texas Surface Water Quality Standards

Section 303 of the CWA requires states to promulgate standards for the protection of water quality based on Federal water quality criteria. Federal water quality criteria are established pursuant to Section 304. The TSWQS are relevant to evaluation of short-term and long-term effectiveness of the remedial alternatives. As discussed in Section 3.1, the RAO was established, in part, to address the TSWQS for PCBs. This ARAR would be addressed by a remedial action that effectively addresses the RAOs.

3.4.1.2 Section 401 Water Quality Certification of the Clean Water Act as Administered by Texas

Section 401 requires that the applicant for Federal permits obtain certification from the appropriate State agency that the action to be permitted will comply with State water quality standards. Although environmental permits are not required for on-site CERCLA response actions, the selected remedy would incorporate elements to comply with State water quality standards if appropriate.

3.4.1.3 Section 404 and 404(b)(1) of the Clean Water Act and Texas Parks and Wildlife Commission Marl, Sand, and Gravel Permit

The CWA Section 404 requires that discharges of fill to waters of the United States serve the public interest. In selecting a remedial alternative including discharge of fill, USEPA would be required to make the determination that the placement of materials into Patrick Bayou serves the public interest as necessary to remediate the Site. The Site includes submerged areas within the Patrick Bayou waterway, as well as areas that are occasionally not submerged. A plan will need to be established that addresses the requirements (to the extent practicable) of Section 404 and 404(b)(1). During design of a remedial action, USEPA may request that any potentially responsible parties prepare a 404(b)(1) report for consideration by the USEPA based on identification of a preferred alternative.

In addition, the State of Texas regulates taking sedimentary material (marl, sand, gravel, shell, and mudshell) from public waters under chapter 86, subtitle F of the Texas Parks and Wildlife Code. If the selected remedy includes dredging, permits would not be required from the State, as the activity would be performed as part of an on-site CERCLA action.

3.4.1.4 Texas Pollutant Discharge Elimination System

Within the State of Texas, the NPDES, which demonstrates compliance with Section 402 of the CWA, is administered by Texas Commission on Environmental Quality (TCEQ) and referred to as Texas Pollutant Discharge Elimination System (TPDES). If the selected remedy includes a discharge to surface water, the discharge would need to comply with the substantive TPDES requirements even though on-site CERCLA actions are exempt from permitting.

3.4.1.5 Rivers and Harbor Act, Texas State Code Obstructions to Navigation, and Port Authority of Houston Marine Construction Permit

The Site is within a navigable waterway that is regulated by USACE under Section 10 of the Rivers and Harbors Act, the State of Texas under the Natural Resources Code, and the Port Authority of Houston under their Marine Construction Permitting authority. The construction in navigable waters of structures (potentially including sediment caps), facilities, and bridges or removal and placement of trees that would obstruct navigation are among the activities that may trigger compliance with the regulations.

3.4.2 Protected Species Requirements

This section addresses requirements of the ESA, the Fish and Wildlife Coordination Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act. The Site is located within an intensely developed industrial area and is not known to provide habitat suitable for any listed aquatic species; however, the Site is approximately 11 miles upstream of Galveston Bay, which provides rearing, spawning, and adult habitat for numerous marine and estuarine fish and invertebrate species including blue crab, black drum, flounder, oysters, spotted sea trout, and shrimp, which are among the species identified as NOAA Trust resources[7]. The Site also provides suitable resting and foraging habitat for migratory birds. The design and overall goal of the remedial action is to improve habitat conditions through the anticipated reduction of contaminants potentially released to the environment. Certain actions may require timing considerations to avoid potential harm of protected species.

3.4.3 Coastal Zone Management and Texas Coastal Management Plan

Federal agency activities that have reasonably foreseeable effects on any land or water use or natural resource of the coastal zone (also referred to as coastal uses or resources and coastal effects) must be consistent to the maximum extent practicable with the enforceable policies of a coastal state's federally approved coastal management program (NOAA 2012). The GLO administers the Texas Coastal Management Consistency certification. Under Texas law, a coastal natural resource area (CNRA) is a coastal barrier, coastal historic area, coastal preserve, coastal shore area, coastal wetland, critical dune area, critical erosion area, Gulf beach, hard substrate reef, oyster reef, submerged land, special hazard area, submerged aquatic vegetation, tidal sand or mud flat, water in the open Gulf of Mexico, or water under tidal influence, as these terms are defined in 33.203 of the Texas Natural Resources Code. The remedial alternatives are reviewed for consistency with ARARs, including coastal uses, in Section 5. Consultation with GLO would be performed, if necessary, as part of remedial design.

3.4.4 Floodplain

Construction, including remedial response, within a floodplain must not restrict flow such that it would create or exacerbate potential flooding. A hydrologic evaluation would be performed during remedial design to assess existing flow conditions at the Site. Modeling would be used, in part, to evaluate potential impacts of the remedial alternatives on the water levels in Patrick Bayou and steps taken to mitigate such problems.

[7] Coastal and Estuarine Hazardous Waste Site Reports, Table 1, accessed October 2013. http://archive.orr.noaa.gov/book_shelf/391_wsr4_patrickbayou.pdf.

3.4.5 Cultural Resources Management

The National Historic Preservation Act and the Antiquities Code of Texas (ACT) have applicability to remedial action at the Site. This section provides a summary of existing information on recorded historic properties and a summary of potentially applicable requirements.

Section 106 of the National Historic Preservation Act, and its implementing regulations at 36 CFR 800, require that Federal agencies take into account the effects of their undertakings on historic properties. The Section 106 process requires agencies to:

- Determine the Area of Potential Effects (APE), defined as "the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist" (36 CFR 800.16(d)).
- Inventory potential historic properties (prehistoric or historic districts, sites, buildings, structures or objects; including Traditional Cultural Properties) within the APE.
- Evaluate the potential historic properties to determine if any are eligible for listing in the National Register of Historic Places (NRHP).
- Assess whether the project will have effects on any NRHP-eligible properties in the APE, and whether the effects will be adverse.
- Resolve any adverse effects to NRHP-eligible historic properties in a Memorandum of Agreement (MOA) describing mitigation measures.
- Consult with interested and affected Indian Tribes, the State Historic Preservation Officer (SHPO), the public, and other interested parties.

The requirements of the ACT (Title 9, Chapter 191 of the Texas Natural Resource Code) and the associated Rules of Practice and Procedure for the ACT (Title 13, Part II, Chapter 26 of the Texas Administrative Code) apply to the project if construction is performed on lands below mean high water, which are owned by the State of Texas. The ACT requires that project information be provided to the Texas Historical Commission for review.

There are no recorded historic properties in the immediate project area, according to the Texas Archaeological Sites Atlas (checked December 4, 2013). The nearest archaeological sites are at least 1 mile from Patrick Bayou. A number of historical markers, primarily related to the Battle of San Jacinto, are located more than 1 mile east of the project area. Three archaeological surveys have been conducted intersecting the project area. Little information is available on the surveys, but records indicate that no archaeological sites were located in the project vicinity during these surveys.

The project area likely contained archaeological materials at some time in the past. The presence of precontact middens and historic early 20th century sites in the vicinity (in addition to the proximity of the historically significant location of the Battle of San Jacinto) indicates that the area was used in the precontact and historic eras. The Site is unlikely to contain archaeological materials, however, as much of the length of Patrick Bayou has been altered by historic and modern industrial activities. A comparison of 1953 and 2012 aerial photographs illustrates the straightening of the bayou (Figure 3-2).

Despite the extensive industrial activity, some upland areas may contain archaeological resources (possibly under modern fill). These areas, especially those at relatively higher elevations, appear to have changed relatively little. For example, the peninsula created where Patrick Bayou joins the HSC may have been a particularly attractive location for use and settlement in the recent and distant past. Remedial action plans would consider potential effects that staging, access, and other activities may have on historically sensitive areas. If necessary, some areas may be designated off limits for construction activities.

To fulfill the requirements of Section 106, the following steps will be implemented during remedial design:

- The APE will be determined based on engineering designs for the selected alternative.
- Project plans will be analyzed by a qualified archaeologist to determine whether any areas with archaeological potential will be impacted within the APE.
- If areas with archaeological potential will be impacted, an archaeological survey will be conducted to identify and evaluate any archaeological historic properties and a report will be prepared documenting the findings of the analysis. Determinations of NRHP-eligibility of any potential historic properties and of potential project effects

should be made by USEPA, in consultation with Texas Historical Commission. Determinations and supporting documentation should be provided to consulting parties.

- If any adverse effects to NRHP-eligible historic properties are identified, USEPA should work with consulting parties to develop mitigation measures and prepare an MOA.

3.4.6 Noise Control Act

Noise abatement may be required if actions are identified as a public nuisance. As the Site is bounded by large industrial facilities and the HSC, noise from construction activity is unlikely to constitute a public nuisance.

3.4.7 Hazardous Materials Transportation and Waste Management

Under nearly any remedial action scenario, aside from the No Action alternative, off-site disposal may be required for limited quantities of waste, such as used personal protective equipment. Some remedial alternatives may require disposal of more significant quantities of material, such as debris. Typically, remedial contractors would be required to package any hazardous materials in appropriate containers and label containers in accordance with Texas Department of Transportation and other applicable requirements. An existing permitted facility (e.g., landfill) would be chosen for any off-site disposal and submitted for approval to USEPA.

4 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section includes the following discussions:

- Preliminary delineation of various sediment management areas (SMAs) at the Site where specific remedial technologies are evaluated.
- Remedial technology considerations specific to this Site, as they apply to the assembly of FS alternatives.
- Assembly of remedial alternatives, which are carried forward into detailed and comparative evaluations against CERCLA criteria in subsequent sections of the FS.

4.1 Delineation of Sediment Management Areas

Preliminary SMAs were delineated that, if addressed, would result in the Site achieving the water quality and benthic risk RAOs. It was further determined that addressing these SMAs will also address the aquatic-dependent wildlife RAO (see discussion in Section 3.3). This section describes the delineation of SMAs. Note that delineation of sediment SMAs 2 through 6 was completed using 2009 data. Refinement of all SMAs is anticipated using new data in the pre-design phase of this project.

4.1.1 Delineation Approach for TSWQS SMA

A single SMA was identified where actions would need to be evaluated for the remedy to achieve the TSWQS RAO. The limits of SMA-1 were delineated using the chemical fate and transport model to estimate the reduction in PCB loading to surface water necessary to achieve the TSWQS total PCB value of 30 ng/L throughout a majority of the Site within a few years following completion of construction. This evaluation considered surface water quality data collected during three separate events (Section 2.6), and fate and transport modeling as described in Appendix A.

Based on the analysis described in Appendix A it was determined that remediation of sediments between stations PB-075 and PB-082 would achieve the necessary load reduction in PCBs to the water column. As described in Section 2.6, additional water column data were collected in 2014 to develop a better understanding of the nature and extent of PCBs in surface water within the concrete-lined channel. Figure 2-18 shows a spatial profile of the

2014 water column data within the concrete-lined channel and throughout Patrick Bayou. This figure shows a relatively small increase in PCB concentration between approximately stations PB-100 and PB-082 (increasing from approximately 5 to 10 ng/L over this reach), followed by a relatively large increase in PCBs between stations PB-082 and PB-075 from approximately 10 to 70 ng/L. Based on these data and surface sediment data from this area, SMA-1 was defined as the 700 linear feet of the concrete-lined channel between stations PB-075 and PB-082. Verification and refinement of the extent of SMA-1 is anticipated in the pre-design phase of this project.

4.1.2 Delineation Approach for Benthic Risk PRG SMAs

To delineate benthic risk SMAs, the benthic risk PRG was applied to the baseline conditions using the 2009 RI surface sediment dataset. Future conditions under each alternative were projected using the surface sediment half-life of PCBs estimated from simulations with the calibrated chemical fate and transport model (Appendix A).

Using the 2009 RI surface sediment data, areas that currently meet the PRG were identified. Areas currently exceeding the PRG were further evaluated based on estimated sediment half-lives for PCBs predicted by the model (Appendix A) to evaluate if natural recovery would reduce surface sediment concentrations below the PRG within a reasonable time frame. Areas that were not predicted to recover naturally to meet the PRG within a reasonable time frame were delineated as benthic risk SMAs. Each element of this analysis is described in more detail in the subsections that follow. Table 4-1 summarizes the results of this analysis for two scenarios: Scenario 1 assumes that no remediation has occurred in SMA-1 (as in Alternatives 1 and 2, described subsequently). Scenario 2 assumes that SMA-1 has been remediated (as in Alternatives 3 and 4 described subsequently), and thus natural recovery rates are faster because of this remediation.

4.1.2.1 Evaluating Baseline Conditions

In the BERA, risk characterization was performed using data collected primarily in 2002 and 2003. However, due to the age of the dataset and the known dynamic nature of the sediment bed and chemistry within the Site, the sediment chemistry data collected in 2002/2003 as part of the sediment toxicity TMDL program are not considered representative of current conditions for the purposed alternatives development in this FS. Data collected in 2009 during the RI are more relevant for establishing the preliminary baseline condition to evaluate alternatives relative to benthic risk because the RI surface sediment dataset is more recent, more comprehensive in terms of spatial coverage, and reflects more current methodology (e.g., high resolution PCB congener analysis) than the BERA benthic risk assessment dataset.

Therefore, the surface sediment RI dataset was used to establish the preliminary baseline condition for analysis of the alternatives. To delineate benthic risk SMAs, Thiessen polygons were defined for each of the 60 surface sediment samples used to map baseline conditions for the FS, and the mean PEL-Q was assigned to each polygon based on the sediment chemistry within that polygon. Using this approach, the mean PEL-Qs for the baseline condition were mapped as shown in Figure 3-1. It should be noted that, based on the 2002/2003 dataset, areas 4A and 6A (see Figure 8-1 in the BERA, Anchor QEA 2011b) had the highest mean PEL-Q values, but the 2009 data indicate that the mean PEL-Q values in these areas have decreased. These decreases are consistent with the characterization of higher net deposition rates in these areas in the STM Report (Anchor QEA 2011c) and thus these decreases should be expected. Conversely, Area 3 in the 2002/2003 dataset was indeterminate from a sediment toxicity perspective, but this area is characterized by relatively low net sedimentation in the STM and thus conditions would not be expected to improve as rapidly as they have in areas 4A and 6A.

4.1.2.2 Evaluating Future Conditions

To evaluate natural recovery and future conditions under different alternatives, estimated sediment half-lives for PCBs in surface sediment were developed using the chemical fate and transport modeling (Appendix A). Using the model-predicted half-lives, the number of years that would be needed for benthic risk areas to achieve the PRG as a result of natural recovery processes was evaluated. Development of the PCB half-lives and their application to the baseline condition are described below.

4.1.2.2.1 Surface Sediment Half-life Estimates

Mechanisms controlling natural recovery of contaminated sediment (e.g., processes such as deposition and degradation) often follow a first order decline (Chapra 1997; Magar et. al. 2009). Thus, the rate of natural recovery for PCBs was estimated by fitting an exponential rate of decline through surface (0-10 cm) sediment PCB concentrations predicted by the chemical fate model for a 24-year simulation period (see Appendix A). Spatially, half-life values were calculated based on spatially-averaged, model-predicted concentrations over 1,000-foot-long segments (i.e., every ten sampling stations) across the Site.

These predicted half-lives were developed based on model simulation of PCBs using data from 2009 and the upper 10 cm of sediments. Inspection of model results indicates that the surface sediment rates of decline predicted by the model are driven by net sedimentation (consistent with the STM described in Anchor QEA 2011c). Thus, it is expected that that the mean PEL-Q would generally recover at the same rate as PCBs, because of this and the following additional factors:

- The mean PEL-Q is predominately driven by PCBs for nearly every sample in the surface RI dataset, as well as the benthic risk assessment WOE dataset. For locations with a baseline mean PEL-Q above the PRG (Figure 3-1), PCBs account for a significant proportion of the overall mean PEL-Q.
- No ongoing sources of PAHs, BEHP, or lead were identified in the RI that would contribute to the incoming sediment load to the Site beyond background inputs of these COPCs from upstream urban runoff.

While using simulated surface sediment PCBs as a representative of mean PEL-Q may introduce some uncertainty in the evaluation of future conditions, this uncertainty is considered relatively minor in the overall assessment and interpretation of future conditions. Note that future baseline evaluations will consider discrete depth zones to better assess MNR. Evaluating discrete depth zones will allow refinement of the bioactive zone and better assessment of MNR in critical horizons.

4.1.2.2.2 Application of Half-lives to Baseline Conditions

To evaluate the rates of natural recovery in sediments with respect to the mean PEL-Q and associated risk to benthos, the number of years for each Thiessen polygon to decrease below the PRG threshold of 7.56 was estimated using the following equation:

$$t = \frac{t_{1/2} \times ln\left(\frac{N_0}{N_t}\right)}{ln(2)}$$

where:

N_t = target mean PEL-Q of 7.56

t = years to achieve N_t

N_0 = year zero (baseline) mean PEL-Q for location (Figure 2-23)

$t_{1/2}$ = half-life estimated from model-predicted surface sediment (0 to 10 cm) PCB concentrations for the 1,000 foot segment containing the location (see Appendix A)

4.1.2.3 Delineation of Benthic Risk SMAs

Using the approach presented in the preceding section (i.e., estimating mean PEL-Q reductions over time using baseline surface [0 to 10 cm] values from 2009 RI data and half-life estimates from the PCB fate model, which are representative of mean PEL-Q changes over time as discussed in Section 4.1.2.2.1), the number of years necessary for natural recovery to achieve the benthic risk PRG was estimated for each mean PEL-Q polygon,. Benthic risk SMAs were then delineated for areas where natural recovery estimates do not reduce the mean PEL-Q below the PRG within ten years. The natural recovery rates used for Alternatives 1 and 2 (described subsequently) do not presume any action has been taken. The natural recovery rates used for Alternatives 3 and 4 assume SMA-1 has been remediated, thus accelerating natural recovery processes. Based on the evaluations described above, Thiessen polygons associated with surface sample locations PB-026, PB-032, PB-036, PB-037, and PB-047.1 were identified as benthic risk SMAs for Alternatives 3 and 4 (Table 4-1).

4.1.3 Delineation of Natural Recovery Areas

Areas of the Site that currently exceed the benthic risk PRG (Figure 3-1), but that are projected to be at or below the PRG within 10 years due to natural recovery will be monitored to assess changes in the mean PEL-Q over time. Thus, the term "Natural Recovery Areas" is defined as representing those areas where baseline data may exceed the benthic risk PRG, but are not otherwise delineated as TSWQS or longer term potential benthic risk SMAs.

4.1.4 Summary of SMA Delineation

Table 4-2 summarizes the SMA identification, location, and primary driver for the delineation. Figure 4-1 shows the approximate limits of SMA-1 through SMA-6, and the Natural Recovery Areas. The actual number and limits of these SMAs and Natural Recovery Areas would be refined by pre-design baseline data collection and additional model calibration, which will be used in an adaptive management process to determine whether, and to what extent remediation of SMAs will be necessary to achieve RAOs. For the purpose of this FS, acreages shown in Table 4-2 were developed as follows:

- For SMA-1, the area was identified using the chemical fate and transport model by iterating on the size of this area during model calibration until a good match occurred with measured surface water results.
- For SMA-2 through SMA-6 and the Natural Recovery Areas, the acreage is based on Thiessen polygons generated using the 2009 surface sediment data.

While these acreages provide a starting point for estimating areas, the remedial alternatives development also includes technology-specific considerations, which in some cases increase the footprint over which action would be taken. For example, if capping were to be implemented, the surface area of the cap might be greater than the SMA that it would be covering to accommodate edge details such as bank anchoring. Remedial technology-specific considerations are discussed in additional detail subsequently in this section of the FS.

4.2 Remedial Technologies Screening

The RATS (Anchor QEA 2013a) identifies General Response Actions (GRAs) and provides initial screening of remedial technologies. The RATS included consideration of institutional controls, natural recovery, in situ treatment, containment, removal, ex-situ treatment, disposal, and beneficial reuse of sediments.

Most of these GRAs were retained for further consideration in the FS. However, specific issues related to certain GRAs were identified, and specific screening decisions were made in the RATS that eliminated certain technologies from further consideration for the Site. Based on the screening presented in RATS, the following remedial technologies were not considered applicable to the Site:

- Treatment by thermal desorption
- Treatment by sediment washing
- Disposal in an unconfined open water site
- Beneficial reuse of sediments

In addition, removal was retained only in limited application to be used if necessary to maintain flood capacity of the channel for an in situ containment remedy.
The following supplemental information regarding GRAs is provided in the specific context of the final set of remedial alternatives for the Site in this FS Report.

4.2.1 Institutional Controls

Institutional controls are administrative measures that are implemented to mitigate risks or to protect the integrity of engineered controls. Institutional controls include “Proprietary Controls,” which are restrictions placed on the use of private property, “Governmental Controls,” which include restrictions on the use of public resources, “Enforcement Tools” that may be imposed by an agency to compel certain actions, and “Informational Devices,” which include notices about the presence of contamination or fishing advisories (USEPA 2012). Institutional controls are discussed in detail in the RATS and are evaluated for this FS in Appendix F, and are considered highly implementable and effective. Institutional controls currently in place, not all necessarily associated with the Site, include restrictions on-site access by the industrial facilities bordering the bayou, maintenance agreements, property use restrictions, Homeland Security requirements, monitoring and notification of waterway uses in the HSC, seafood consumption advisories in the HSC and Galveston Bay, and associated public outreach and education (Anchor QEA 2013a). Institutional controls implemented by the members of the JDG are expected to remain in place for the foreseeable future, and as such are integral to any remedial alternative selected for the Site.

4.2.2 Monitored Natural Recovery

As outlined in USEPA's Sediment Remediation Guidance (USEPA 2005), MNR is a remedy for contaminated sediment that typically uses ongoing, naturally occurring processes to contain, destroy, degrade, or reduce the bioavailability or toxicity of chemicals in sediment and associated surface water. MNR may rely on a wide range of naturally occurring processes to reduce risk to human and ecological receptors. These processes may include: 1) physical; 2) biological; and 3) chemical mechanisms that act together to reduce the risk posed by the chemicals. Depending on the chemicals and the environment, this risk reduction may occur in a number of different ways, including destruction (degradation or transformation) of COCs to less toxic chemicals, reduced mobility of COCs, burial, or dispersion.

MNR would entail design and implementation of a sampling and analytical program to monitor the progress of natural recovery. Sampling would be conducted at a representative range of locations and at appropriate time intervals to allow trends in concentrations in surface water and sediments to be assessed. Example sampling and analysis programs could include sampling of surface water, porewater, and sediment. Each component of the MNR remedy is described in more detail in the following sections. Details of the monitoring plans for each component, including data quality objectives and decision rules, would be developed during the remedial design phase.

4.2.2.1 Monitored Natural Recovery Surface Water Monitoring

To evaluate the effectiveness of MNR to achieve the Salt Water Aquatic Life Chronic PCB TSWQS of 30 ng/L, periodic monitoring of PCBs in surface water would be required. To develop costs for the MNR alternative, it has been assumed that monitoring of surface water PCB concentrations would be required at up to five locations. Locations identified for the MNR evaluation would be determined in consultation with USEPA, and for purposes of this FS assume up to three locations within the Site, one location upstream of the Site, and one location in the HSC.

Sampling performed in 2014 as part of the supplemental surface water sampling program in support of the modeling effort (Appendix D) would be used to establish baseline conditions for this media. Monitoring would occur at a frequency and for a duration determined in consultation with USEPA; for purposes of this FS, up to ten monitoring events have been assumed over a 30 year period. Long-term monitoring may require more or less time than expected; adaptive Site management would be used to adjust the time frame and the design of the monitoring program as appropriate.

4.2.2.2 Porewater Monitoring

The concentration of contaminants in porewater, particularly non-polar organics (e.g., PCBs, PAHs) and divalent metals, has been demonstrated to be a significant predictor of sediment toxicity (USEPA 2005, 2008). Reducing porewater concentrations through treatment will reduce the ability of compounds, such as, PCBs to bioaccumulate into food items for wildlife receptors. Thus, porewater monitoring would be an important component of monitoring remedy effectiveness for treatment technologies that are intended to limit exposure through reductions in porewater concentrations of target COCs. If treatment technologies are part of an alternative, porewater monitoring may be necessary to evaluate the effectiveness of the treatment. For example, to evaluate the reduction in benthic risk due to treatment, porewater sampling would include PCBs, PAHs, lead, and BEHP. Monitoring would occur at a frequency and duration determined in consultation with USEPA; for purposes of this FS, up to ten monitoring events have been assumed over a 30 year period. Long-term monitoring may require more or less time than expected; adaptive site management would be used to adjust the time frame and design of the monitoring program as appropriate.

4.2.2.2 Surface Sediment Monitoring

To evaluate the effectiveness of natural recovery to achieve the PRG for benthic risk, monitoring the concentration of primary and secondary ICs in surface sediment would be performed. For FS purposes, it has been assumed that monitoring of PCBs, PAHs, lead, and BEHP would be performed on a composite basis over selected subareas within the Natural Recovery Areas. Within the Natural Recovery Areas, surface sediment samples would be collected at previously-sampled RI surface sediment locations and composited over an appropriate subarea (e.g., a station range based on similar rates of expected recovery). Sampling would be performed prior to remedy implementation and periodically thereafter at time intervals determined in consultation with USEPA. The FS assumes up to ten monitoring events would be implemented across seven Natural Recovery subareas over a 30-year period.

Long-term monitoring may require more or less time than expected; adaptive site management would be used to adjust the time frame and sampling design for surface sediment monitoring as appropriate.

4.2.3 Containment

In situ containment refers to the placement of an engineered subaqueous cap on top of chemically impacted sediment that will remain in place. A cap would be designed to effectively contain and isolate such sediments from the biologically active surface zone. As described in *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005), in situ caps can quickly reduce exposure to chemicals and typically require less infrastructure than ex-situ technologies (e.g., dredging, dewatering, treatment, and disposal). Since capping leaves contaminated sediments in place, long-term monitoring is typically a component of in situ containment to verify that the cap is stable (i.e., not damaged) and continues to effectively isolate chemicals, or sufficiently attenuate chemical mobility through the cap (USEPA 2005).

In situ caps isolate chemically impacted sediments from the environment by use of natural (e.g., sand) or constructed (e.g., geosynthetic layers or concrete) products. Depending on the proposed remedial design for a site, a cap can consist of a single sediment layer to isolate chemicals or can be designed as a multi-layered system consisting of a combination of sediment, geosynthetic, and armor layers.

Aggregate caps and Articulated Concrete Block Mat (ACBM) caps are two methods of containment that were described in the RATS. Placement of aggregate or ACBM caps in the channel may be combined with treatment and/or removal GRAs, which are discussed subsequently in this FS. To the extent that containment is a component of the remedy, the containment would be designed, monitored, and maintained in accordance with USACE and USEPA capping guidance (USEPA 1998). In situ capping, as discussed in USEPA guidance

(USEPA 2005) is a demonstrated technology that has been selected by USEPA for sediment remediation sites across the United States (USEPA 1998; ITRC 2014).

Compared to removal-focused approaches, in situ capping has a disadvantage, in that caps require monitoring and maintenance to confirm their protectiveness. In addition, caps disrupt the benthic community. Aggregate caps cover the near surface benthos, potentially smothering it. ACBM caps create a concrete surface layer that is inhospitable to the benthic community for a period of time until future sediment deposition on top of the ACBM improves the surface substrate.

4.2.3.1 Aggregate Caps

Aggregate caps typically consist of a base layer for chemical isolation (typically sand-sized materials containing an adsorptive amendment as needed), and, as necessary, a filter and/or armor stone surface treatment. The surface armor layer of larger-sized rock prevents the loss of the chemical isolation layer during high flow events. A multi-layered cap consisting of chemical isolation, filter, and armor layers can be on the order of 2 or more feet thick, which can reduce the capacity of the channel to handle flood events. To maintain flood capacity when using an aggregate cap, excavation of the channel bed could be necessary prior to cap construction. As USEPA has described (USEPA 2005), excavation of sediments can result in the generation of dredging residuals and contaminant losses, as further discussed in Section 4.2.5 of this FS.

Required armor gradation is a function of the shear stresses that need to be resisted, which vary throughout the channel. Appendix B provides a preliminary evaluation of the size of armor that would be needed for the various SMAs, based on the channel configuration in that area and the worst-case shear stress that might occur during a design-level flood event. Table 4-3 provides a summary of the armor stone size, presented as d_{50} (the size beyond which at least 50 percent of the cap aggregates are larger) for each SMA, sized to resist a 100-year flow event. The minimum required armor thickness is often taken to be twice the d_{50} dimension. Based on the relatively thick armor layer requirements, aggregate caps were not carried forward in the FS as the assumed containment technology. However, more refined Site modeling may be performed during remedial design that might conclude that aggregate caps could be an appropriate technology in certain areas, and thus this technology has been retained for remedial design.

4.2.3.2 Articulated Concrete Block Mat Caps

ACBM systems are used to provide erosion protection to underlying soil from the hydraulic forces of moving water. An ACBM system is comprised of a matrix of individual concrete blocks placed together to form an erosion-resistant revetment with specific hydraulic performance characteristics. The term "articulated" implies the ability of the matrix to conform to minor changes in the subgrade while remaining interconnected with geometric interlock and/or additional system components such as cables. Because of the low profile of the ACBM cap, excavation prior to ACBM placement is not assumed necessary for maintaining channel flood capacity. This advantage, as well as the fact that ACBM can often be placed in areas with limited equipment access, means that ACBM is an ideal choice for channels with limited flood capacity and/or access constraints, both of which are issues for Patrick Bayou.

Prior to ACBM installation, the cap footprint would be swept to remove large debris, and the banks of the channel would be prepared for anchoring the ACBM fabric. Preparation of the banks to allow construction access and anchoring would require a corridor approximately 20 to 30 feet wide that would be heavily disturbed during construction. For ACBM installation, the channel would first be lined with geotextile; where a treatment layer is a component of the cap, a Reactive Core Mat (RCM) layer could also be added. A RCM would be designed specifically for the Site, in consultation with suppliers and considering site-specific COC concentrations and other factors. A typical RCM consists of two layers of geofabric with a reactive media sandwiched between the layers.

Following placement of the geotextile liner (and RCM if used), ACBM fabric panels would be placed and secured in the channel, filled with concrete, and allowed to cure. The FS assumes that the ACBM will be placed bank to bank in the channel. Because of this, the SMA ACBM areas used in the cost estimates (Appendix C) are larger than the actual SMA delineation areas described in Table 4-2.

4.2.4 Treatment

Treatment technologies can be an effective remedial action given the proper chemical properties of the Site-specific COCs and the physical constraints of the Site. The results of the treatment technology review presented in the RATS (Anchor QEA 2013a, Appendix A), and the screening of in situ treatment technologies is summarized in this section.

In general, in situ sediment treatment technologies include immobilization of the COCs with the addition of sequestering agents (such as activated carbon [AC]), biological or chemical degradation, other forms of immobilization, and other potentially appropriate treatment technologies to reduce the toxicity, mobility, or volume of sediment chemicals while leaving sediments in place. As discussed in the RATS (Anchor QEA 2013a), adsorbent amendments may be added to the sediment in situ to effectively reduce the mobility and bioavailability of the Site-specific COCs. Adsorbent materials may also be added to cap fill, as discussed in Section 4.3.3. The primary exposure medium of concern is the shallow sediment, within 10 cm of the sediment-water interface. The consideration of in situ treatment technologies is focused on the top 10 cm of sediment within the Site as this area includes the biologically active zone (see Section 2.5.2). However, as indicated above, the biologically active zone extents will be evaluated in more detail during remedial design.

Treatment as a response action could be accomplished with the addition of AC to sequester COCs, reducing surface water concentrations of PCBs and reducing bioavailability of COCs in porewater to address benthic risk and aquatic-dependent wildlife risk. For sediment cleanup projects, treatment with AC could be as direct application to the sediment surface, mixed into the sediments, mixed into a sand cover layer, or incorporated as a component of an isolation cap. Treatment can disturb the benthic community and cause short-term impacts, particularly where amendments are physically mixed or blended into the surface. In these cases, research indicates that within about a year following treatment, the benthic community would be expected to recover such that treated areas would be similar to untreated areas (Alcoa 2010). Treatment can be applied in a very targeted fashion, as needed, which will minimize impacts to benthos to the maximum extent practicable.

For purposes of this FS, two different treatment options were assumed, depending on which area of the Site is being addressed. Option 1 assumes the use of a RCM, which is two geotextile layers with a reactive medium between the geotextile layers. The RCM mat considered for this FS assumes dosage with granular AC at a mass per unit area of 0.4 pounds per square foot, although different dosages could be used if determined appropriate during remedial design. The RCM would be an underlayment to an ACBM isolation cap to provide enhanced protectiveness for the remedy by reducing the mobility and bioavailability of the COCs. For purposes of the FS, Option 2 assumes mixing, or "tilling" bulk AC into the upper 4 to 6 inches of surface sediments to address potential porewater issues associated with benthic risk and bioaccumulation of PCBs into food items consumed by aquatic-dependent wildlife. During remedial design, application methods such as surface spreading without mixing will also be considered, where appropriate (such as low energy areas of the Site). In this option, a dosage of 5 percent by dry weight AC would be mixed into surface sediments using a tiller or auger system. Based on existing sediment data, the dry unit weight of sediments is on the order of 0.5 tons per cubic yard. Thus, for purposes of FS alternatives evaluation, the Option 2 treatment would entail dosing sediments 20 tons per acre, or 0.9 pounds per square foot AC. The actual dosage used would be determined during remedial design evaluations.

To evaluate treatment Option 1, chemical isolation modeling was performed as described in Appendix B to evaluate the long-term performance of a RCM in sequestering PCBs from the sediments. For the RCM product considered, near-surface porewater concentrations were predicted by the model to be reduced by over 99 percent for at least 100 years (Appendix B). This means that the RCM will result in immediate reductions in surface porewater concentrations and will also achieve significant long-term reductions. The actual dosage and reagent for a RCM would be determined during remedial design based on more detailed, SMA-specific modeling.

Treatment Option 2 includes mixing AC into surface sediments to reduce potential concentrations of mean PEL-Q chemicals in porewater to address benthic risk and bioaccumulation of PCBs. Treatment of sediments has been studied extensively, and is a well-documented approach to addressing hydrophobic organic COCs, which are the primary benthic risk drivers for this Site. A large body of literature documenting actual performance of treatment projects shows that AC can reduce bioavailability of hydrophobic organic COCs by more than 60 to 90 percent (Janssen and Beckingham 2013). Sediment treatment using a blended cover, direct application and/or mixing of AC into sediments has been demonstrated on more than 25 projects over the last decade, including CERCLA projects (Patmont et al. 2014). Detailed guidance has been prepared for the assessment, design, and monitoring of sediment treatment remedies, including considerations regarding the long-term monitoring of treatment effectiveness in reducing bioavailability (ITRC 2014). If treatment is selected as a remedial technology for the Site, a bench-scale treatability study may be performed to evaluate the appropriate reagent type and dosage to optimize treatment effectiveness.

4.2.5 Removal

Removal, if selected as a component of the preferred alternative, would only be used to the extent necessary to offset any loss of channel flood capacity from capping (i.e., if a thick aggregate cap were selected as the remedy). As discussed in the RATS (Anchor QEA 2013a), virtually all dredging projects result in some degree of resuspension, release, and residuals, despite use of Best Management Practices (BMPs)(USEPA 2005; NRC 2007; USACE 2008a; Bridges et al. 2010). Empirical data from numerous sediment remediation projects indicate that residual contamination is a common occurrence that frequently limits the overall protectiveness of removal (Patmont and Palermo 2007; NRC 2007). USEPA guidance on sediment remediation states that "there should not be necessarily a presumption that removal of contaminated sediments from a water body will be necessarily more effective or permanent than capping or MNR" (USEPA 2005). Further, as described in the RATS and in Section 2 of this FS, the subsurface profile of Site-specific COC concentrations increase with sediment depth. Thus, the effectiveness of removal decreases with increasing depth, because the relative concentration of the post-dredge sediment surface, and the relative concentration of dredge residuals increase with depth. As a result, removal alternatives are considered to present greater risk compared to containment alternatives. Finally, research indicates that sites like Patrick Bayou with hard bottom conditions and/or debris have higher potential releases during dredging (USACE 2008a).

If dredging to accommodate a cap for containment and/or treatment is sufficiently deep such that the full depth of COC would be removed, there would be no need for a cap, and thus dredging residuals would be managed by placing clean sediment cover over the dredge footprint. The need for and required thickness of post-dredge cover would be assessed as part of the remedial design.

Construction-related releases associated with dredging reduce the long-term effectiveness of these approaches and may potentially re-distribute impacted sediments downstream and/or off-site. Post-construction monitoring data have shown that dredging-based cleanup remedies can increase fish tissue concentration of contaminants, even several years following completion of dredging (e.g., at the Commencement Bay and Duwamish Waterway Superfund Sites; Patmont et al. 2013). To the extent that dredging-related releases occur, they reduce the overall effectiveness of a dredging remedy and under USEPA sediment remediation guidance (USEPA 2005), which is a consideration during the comparative net risk analysis of the remedial alternatives under consideration.

4.2.5.1 Removal Best Management Practices

Operational and engineering controls (rigid and flexible barriers) are often used to the extent practicable to mitigate potential releases. However, because the Site is part of a stormwater drainage system, the implementation of controls in the channel would likely be extremely challenging. Rigid controls would block stormwater flows and could result in flooding upstream, a situation likely very much unacceptable to the City of Deer Park and upstream residents and businesses. If low water levels or high flow velocities occur in the channel, which, as described in the STM Report (Anchor QEA 2011c) are common at the Site, flexible barriers, like turbidity curtains, will likely be ineffective in controlling releases. Turbidity curtains are considered ineffective at current velocities greater than approximately 0.5 meters per second (Francingues and Palermo 2005).

In addition to these Site-specific considerations, case studies on engineering controls have shown that they:

- May have limited effectiveness
- Are subject to leakage
- Accumulate resuspended sediments at the base of the barrier, which is impossible to completely capture
- Have other technical limitations (USACE 2008b; Anchor 2005; Anchor QEA and

Arcadis 2010)

Further, use of rigid barriers can result in unintended consequences, such as concentration of dissolved-phase chemicals inside the barrier, localized scour adjacent to the barrier, and/or the spread of contaminants during structure removal (Ecology 1995; Konechne et al. 2010; Anchor QEA and Arcadis 2010). Flexible barriers such as turbidity curtains will suffer from suspended sediment losses because these types of barriers are not truly water-tight (USACE 2008a; USACE 2008b; Francingues and Palermo 2005; Anchor 2005; Anchor QEA and Arcadis 2010).

4.2.5.2 Disposal

The RATS retained both upland confined disposal facility (CDF) and landfill disposal as options for the selected alternative. In development of the alternatives presented in this FS, there have been no changes to the disposal considerations presented in the RATS.

ACBM capping would require a debris removal phase prior to cap placement; these debris would be shipped off-site for landfill disposal. If excavation were necessary to accommodate a cap, excavated sediment could potentially be disposed of either on-site in a constructed CDF (such as an inoperative stormwater pond), or off-site in a landfill. Disposal decisions would be made during the remedial design.

4.3 Assembly of Remedial Alternatives

Remedial alternatives were developed to evaluate candidate methods for achieving the RAOs. Specifically:

- The fate and transport model (Appendix A) was used to assess the effectiveness of the remedial alternatives in reducing concentrations of PCBs in surface water to below the TSWQS of 30 ng/L. Reductions in surface water PCB levels also will address the wildlife RAO (see Section 3.3).
- SMAs were designated to evaluate the effects on surface water quality, benthic risk, and risks to aquatic-dependent wildlife from performing a remedial action in these areas, as described in Section 4.1.

The locations of the SMAs are shown on Figure 4-1. The results of the fate and transport and MNR modeling are discussed in Section 5 in the context of the effectiveness of the remedial alternatives in reducing the concentrations of PCBs in surface water, and in reducing benthic risk and aquatic dependent wildlife to acceptable levels within a reasonable time frame, which, for purposes of FS evaluations, is considered to be 10 years.

The alternatives are presented below.

4.3.1 Alternative 1 – No Further Action

The No Further Action alternative serves as the baseline of comparison for the other remedial alternatives. The NCP requires the development and evaluation of the No Further Action alternative (40 CFR 300.430(e)(6)).

4.3.2 Alternative 2 – Monitored Natural Recovery

Alternative 2, MNR, relies on natural processes to reduce benthic risks to acceptable levels, to meet the TSWQS, and to address the aquatic-dependent wildlife RAO while monitoring recovery over time to verify remedial success. Modeling, presented in Appendix A, projects that the ongoing sedimentation at the Site will reduce PCB concentrations (and thus mean PEL-Q and toxicity) in surface sediment and PCBs in the water column over time.

Alternative 2 would be implemented under an Adaptive Management framework, and would generally be conducted in the following sequence and include the following components:

- Data collection, and evaluation of natural recovery, including evaluation of the need for and limits of remedial actions;
- Continued sampling and analysis during the natural recovery period, including evaluation of recovery effectiveness;
- Maintenance of the existing institutional controls, which include restrictions on-site access by fencing, use restrictions, maintenance agreements, facility security and Homeland Security protocols.

Figure 4-2 presents a process flow diagram for the adaptive management framework that would be used, including the sequence of sampling, evaluation, and decisions that would be made under all alternatives.

The fate and transport model uses an empirically-defined PCB source to represent observed PCB loads in the concrete-lined channel, and for purposes of predicting natural recovery it is assumed that this source would not further attenuate (see Appendix A). Based on this conservative assumption, the model simulation of Alternative 2 predicts that more than 19 years of natural recovery would be required before water column PCB concentrations decrease below the TSWQS of 30 ng/L. However, water column PCB data collected in 2014 demonstrate that PCB levels are much lower in 2014 when compared to 2009 and 2011 levels (see Section 2.6). It is difficult to account for this reduction in the model parameters, and similar reductions could be observed in the future. This is a key area of uncertainty for the purposes of developing remedial alternatives for the FS, and reducing that uncertainty should be considered as part of the remedial design and adaptive management process for the Site.

To address the uncertainty in attenuation and the potential impacts of this uncertainty on natural recovery rates, an empirical evaluation of natural recovery was also conducted based on the water column data (Appendix E). This analysis indicates that water column PCB concentrations decreased at a half-life of approximately 3 to 6 years between 2009, 2011, and 2014. If these observed rates of decline continue into the future, it is expected that water column PCB concentrations would decrease below the TSWQS within 2 to 7 years (depending on location; Appendix E) by natural recovery processes alone. Thus, monitoring would be used to evaluate progress towards such predictions as part of this alternative.

To evaluate natural recovery for addressing benthic risk, and also for addressing the aquatic-dependent wildlife RAO, a sediment chemistry based approach was also evaluated for Alternative 2 (see Appendix A). In the BERA, toxicity in Site sediments was predicted using the mean PEL-Q model (Anchor QEA 2013c) as described in Section 2.6 of this FS. Sediment half-life estimated based on PCB fate modeling, presented in Appendix A, was used to project reductions in mean PEL-Q values over time. Based on this evaluation, the natural recovery at most stations would achieve the benthic risk PRG within 10 years or less. However, the benthic risk PRG is not met within 10 years at nine discrete locations (PB-026, PB-032, PB-036, PB-037, and PB-047.1, PB-053A, PB-059, PB-063.1, and PB-069, Table 4-1), assuming no action has been taken in SMA-1 to address the TSWQS[8].

In this alternative, it is expected that MNR monitoring would be conducted for surface water and sediment chemistry as described in Section 4.2 at various locations throughout the Site to evaluate whether the observed declines in surface water and sediment concentrations continue into the future, and whether the benthic risk PRG is being met. This alternative also includes maintenance of the existing institutional controls, which include restrictions on-site access by fencing and facility security protocols. Figure 4-3 depicts a plan view for Alternative 2. The estimated cost for this alternative is $710,000 (Appendix C).

4.3.3 Alternative 3 – Monitored Natural Recovery, SMA-1 Capping, and SMA-2 through SMA-6 Treatment

Alternative 3 would be implemented using an Adaptive Management framework and generally be based on the following sequence and includes the following components:

- Pre-design surface water and sediment data collection, model recalibration, refinement of SMA extent, and evaluation of natural recovery, including evaluation of the need for and limits of remedial actions in SMA-1 through SMA-6;
- Capping of SMA-1 with ACBM and RCM if surface water PCB concentrations do not continue to decline at a rate consistent with that observed between 2009, 2011, and 2014;
- Treatment with activated carbon of surface sediments in SMA-2 through SMA-6 if the target mean PEL-Q is not projected to be achieved within 10 years based on model recalibration results;
- MNR and associated monitoring for those areas where MNR is suitable based on pre-design data collection results;
- Monitoring and maintenance of capping and treatment remedies, if implemented; and
- Maintenance of the existing institutional controls, which include restrictions on-site

[8] For Alternatives 3 and 4, consistent with the Adaptive Management approach employed throughout the RI/FS, the evaluation of natural recovery for benthic risk assumes that the first step in the remedial process is remedial action at SMA-1 to address the TSWQS. In addition to addressing the TSWQS, remedial action in SMA-1 would also be expected to accelerate natural recovery, and thus fewer locations are identified under Alternatives 3 and 4 where the benthic risk PRG is not met within 10 years. See Table 4-1.

access by fencing, use restrictions, maintenance agreements, facility security and Homeland Security protocols, and advisories within the HSC and Galveston Bay.

Consistent with the Adaptive Management approach employed throughout the RI/FS, pre-design data collection, model recalibration, refinement of SMA extent, and evaluation of ongoing natural recovery would be conducted based on baseline water column, porewater, and sediment chemistry pre-design data collected following the FS. In the event that the pre-design baseline sampling and recovery model reevaluation does not indicate acceptable natural recovery (i.e., indication of not meeting the TSWQS within a reasonable time frame, or an unacceptably long time to achieve the benthic risk PRG), capping of SMA-1 and/or treatment in SMA-2, -3, -4, -5, and/or SMA-6 would be implemented, as appropriate.

For FS purposes, it has been assumed that ACBM would be the technology used for capping, however aggregate caps may be determined appropriate and selected for certain areas in SMA-1, as determined during remedial design. For treatment, addition of AC into surface sediments has been assumed using augers, tines, or similar technology.

The modeling presented in Appendix B assumes that 2 layers of RCM underlayment could be necessary due to uncertainty in the source loading mechanism of PCBs in SMA-1. The actual thickness, granular AC dosage, and design of the RCM would be determined during remedial design. As shown in the Figure 4-4, the capping in SMA-1 would involve installing ACBM with an underlayment of AC RCM in the channel. SMA-1 extends for a length of approximately 700 feet along the bayou channel, from station PB-075 to PB-082. With bank-to-bank widths ranging from approximately 50 to 100 feet, the surface area of capping is 62,000 square feet (1.6 acres) for this alternative. However, the actual footprint and size of SMA-1 would be more thoroughly delineated during remedial design by collecting additional sediment, surface water, and porewater data, as appropriate, and revisiting the modeling if necessary.

For the purpose of this FS, treatment of SMA-2 through SMA-6 involves mixing AC into the top 4 to 6 inches of surface sediments. The combined surface area of these SMAs is approximately 4.3 acres[9]. With bank-to-bank widths typically on the order of 100 to 150 feet (and in the case of SMA-4 a bank-to-edge distance of 250 feet), only a portion of the treatment area could be addressed with land-based equipment such as a long-reach excavator. Treatment areas located more than approximately 50 feet from the shoreline would need to be addressed using a shallow-draft barge-mounted machine equipped with a mixing tool such as an auger or tines. Figure 4-5 depicts conceptual treatment implementation concepts, including mixing of shallow sediments from the bank and from barge-mounted equipment. Figure 4-5 also depicts concepts for surface application of amendments, which will be considered during remedial design as an alternate approach that minimizes sediment disturbance, and that may be applicable for low-energy areas of the Site.

The actual treatment area footprint would be more thoroughly delineated using pre-design sediment and surface water data, and updating and refining the MNR modeling as appropriate.

Costs for Alternative 3 were developed for the FS based on the following assumptions:

- Demolition of the concrete-lined portion of the existing channel is not necessary and that contractors would be able to install the ACBM over the existing concrete;
- SMA-1 would not require dredging prior to installation of the ACBM because of the low profile of the ACBM;
- The ACBM will be placed from one top of bank (TOB) to the other TOB in the channel;
- The RCM would be placed at the base of the channel but not along the banks;
- There are no channel or TOB access or structure restrictions for installation of the cap;
- The railroad (CSX Corporation) would allow placement of the cap around the train trestle;
- Concrete trucks and/or concrete pumps would have sufficient access to the channel;
- Treatment would be performed either from the bank using a long-reach excavator, or

[9] While this represents the acreage based on Thiessen polygons, the FS cost development adds a 20 percent contingency to this area to account for engineering design considerations and potential changes to lateral extents as may be determined by pre-design sampling.

from a shallow-draft barge-mounted machine equipped to mix the AC into the top 6 inches of sediment.

Based on the production rates provided by ACBM contractors, as well as prior project experience and pilot studies of in situ treatment, the duration of construction for this alternative is estimated to be 5 to 7 months. This alternative is estimated to require approximately 3,050 hours of heavy equipment operations.

Using construction worker injuries and fatality rates published by the U.S. Department of Labor (USDL 2011), Alternative 3 is estimated to result in approximately 0.17 lost time injuries, and approximately 0.0007 fatalities as a result of construction (Table 4-4).

The cost of this alternative is estimated to be approximately $6 million (Appendix C).

4.3.4 Alternative 4 – Monitored Natural Recovery and SMA-1 through SMA-6 Capping

Alternative 4 would be implemented using an Adaptive Management framework, and would generally be conducted in the following sequence and include the following components:

- Pre-design data collection and natural recovery evaluations as described for Alternative 3;
- Capping based on the results of pre-design sampling and MNR evaluations as follows:
- SMA-1: capping with ACBM and a RCM underlayment, and MNR;
- SMA-2 through SMA-6: capping with ACBM but no underlayment, and MNR;
- MNR and associated monitoring for those areas where MNR is suitable based on
- pre-design data collection results;
- Monitoring and maintenance of containment and treatment remedies, if implemented; and
- Maintenance of the existing institutional controls, as described for Alternative 3.

The ACBM cap will effectively eliminate an exposure pathway between benthos and surface sediments because it creates a hard concrete barrier on the sediment surface. Because SMA-2 through SMA-6 were identified as benthic risk areas, the use of ACBM alone (without a

RCM underlayment) is considered an appropriate capping technology to achieve RAOs for these SMAs. The use of this technology also will address the aquatic-dependent wildlife RAO because it will reduce the bioavailability and therefore bioaccumulation of PCBs.

Anchoring of the ACBM material in SMA-4 could require placing the cap from bank to bank, even though the edge of this SMA is located mid channel. Thus, for example, the cost estimate for capping using ACBM in SMA-4 assumes approximately 3.5 acres of ACBM would be needed to cover this 1.6 acre area. For capping SMA-2 through SMA-6, the Thiessen polygon area of 4.3 acres (Table 4-2) is increased to 10.1 acres when bank-to-bank capping, and a 20 percent contingency on areas is included, as reflected in the FS costs (Appendix C). It may be possible to terminate the edge of the ACBM cap beneath the water mid-channel, or it may be more cost effective to use a granular cap for this particular SMA. If the pre-design sampling and natural recovery evaluation indicate that capping of SMA-4 is necessary, the actual details for implementing this cap, like all SMAs, (including selection of capping technology and cap footprint limits) would be determined during remedial design. Figure 4-6 presents a plan view of Alternative 4. Figure 4-7 depicts typical ACBM details.

Based on the production rate from ACBM contractors and prior projects, the duration of construction for this alternative is estimated to be 5 to 7 months (Table 4-4). This alternative is estimated to require approximately 3,250 hours of heavy equipment operations.

Using construction worker injuries and fatality rates published by the USDL (USDL 2011), Alternative 4 is estimated to result in approximately 0.17 lost time injuries, and approximately 0.0007 fatalities as a result of construction (Table 4-4).

Costs for Alternative 4 were developed for the FS based on the following assumptions:

- Demolition of the concrete-lined portion of the existing channel is not necessary and that contractors would be able to install the ACBM over the existing concrete;
- None of the SMAs would require dredging prior to installation of the ACBM because of the low profile of the ACBM;
- The ACBM will be placed from one TOB to the other TOB in the channel for anchoring requirements;
- RCM would only be used in SMA-1. The RCM would be placed at the base of the

channel but not along the banks;

- There are no channel or TOB access or structure restrictions for installation of the cap;
- The railroad (CSX Corporation) would allow placement of the cap around the train trestle;
- Concrete trucks and/or concrete pumps would have sufficient access to the channel.

The estimated cost for this alternative is approximately $10.7 million.

5 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The detailed evaluation of remedial alternatives is based on consideration of the following criteria, as required by the NCP, 40 CFR Section 300.430(e)(9):

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness
4. Reduction of toxicity, mobility or volume (TMV)
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The first two criteria, overall protection and compliance with ARARs, are identified as threshold criteria in 40 CFR Section 300.430(f). Remedial alternatives must address the threshold criteria to be selected as the final remedy, although ARAR waivers are considered in some circumstances. The next five criteria are identified as primary balancing criteria. The comparative analysis in Section 6 considers the anticipated performance of the remedial alternatives relative to these balancing criteria. The final two criteria, identified as modifying criteria, are considered by USEPA in preparing the Record of Decision based on consultation with the State environmental agency and a review of public comments received in response to the FS and the proposed plan. As such, State and community acceptance are not considered directly in this FS and will be evaluated by USEPA separately after public comments are received on the proposed plan. Each threshold and balancing criterion is briefly defined below:

- Overall protection is an evaluation of whether the remedial alternative can adequately protect human health and the environment. This may be expressed as an assessment of whether the remedial alternative addresses all of the RAOs, which are identified and described in Section 2.
- Compliance with ARARs is an evaluation of whether the remedial alternative addresses or can be implemented in compliance with all of the ARARs, which are identified in Table 3-2.

- Long-term effectiveness is an evaluation of the ability of the remedial alternative to reliably maintain protection of receptors.
- Reduction of TMV is an evaluation of the degree to which treatment or recycling of affected media is used to reduce the toxicity, mobility or volume of contaminated media, particularly principal threats.
- Short-term effectiveness is an evaluation of both the time required for the remedial alternative to achieve full protection and the degree to which potential risk to human health and the environment is increased during implementation of the remedy, considering measures that may be used to mitigate short-term risks. The short-term effectiveness evaluation also includes an evaluation of the sustainability of the remedial alternative in conformance with the USEPA Region 6 Clean and Green Policy (USEPA 2009).
- Implementability is an evaluation of factors that may impede the implementation of the remedy, considering technical and administrative factors. Technical factors include consideration of whether the remedial alternative involves the use of well demonstrated technologies, readily available equipment and materials, and whether any physical conditions of the Site that may impede implementation. Administrative factors include consideration of whether implementation of the remedial alternative might be impeded by the need to obtain approvals from nearby landowners or public agencies.
- Cost is an evaluation of construction and long-term operation, maintenance, and monitoring costs. A present-worth cost analysis is typically used to evaluate the total cost of remedial alternatives.
- Assessment of State concerns may not be completed until comments on the RI/FS are received but may be discussed, to the extent possible, in the proposed plan issued for public comment. The State concerns that shall be assessed include the following: 1) The State's position and key concerns related to the preferred alternative and other alternatives; and 2) State comments on ARARs or the proposed use of waivers.
- Community acceptance assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received.

This section describes the individual analyses for each of the alternatives. Table 5-1 summarizes the key discussion points from this section for each of the evaluation criteria.

5.1 Alternative 1 – No Further Action

5.1.1 Threshold Criteria

5.1.1.1 Overall Protection of Human Health and the Environment

Existing data indicates that ongoing deposition of relatively clean sediment is occurring at the Site independent of any specific actions by the Respondents, which will continue to reduce surface water concentrations of PCBs, and surface sediment concentrations of PCBs, PAHs, lead, and BEHP over time. However, Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment because it does not provide for monitoring to evaluate the progress of natural recovery. Without monitoring, there would be no way to verify that surface water quality objectives are being met over time, or that benthic and aquatic dependent wildlife risks are decreasing to acceptable levels, and overall protectiveness of the remedy could not be assessed.

5.1.1.2 Compliance with ARARs

Compliance with ARARs was not assessed for Alternative 1 because it does not meet the threshold criterion of overall protection of human health and the environment.

5.1.2 Balancing Criteria

Because this alternative does not meet threshold criteria, the balancing criteria were not evaluated in this FS.

5.2 Alternative 2 – Monitored Natural Recovery

5.2.1 Threshold Criteria

5.2.1.1 Overall Protection of Human Health and the Environment

Alternative 2 potentially meets the threshold criterion of protection of human health and the environment through MNR over time, however natural recovery rates would need to be periodically assessed by collecting additional data and evaluating actual natural recovery trends for the Site to ensure the recovery time frame was acceptable. Deposition of relatively clean sediments into the bayou would provide isolation of impacted sediments from surface water, reducing water column concentrations. Analysis of existing surface water data indicate reductions in PCB concentrations between 2009 and 2014, and reductions in PCB flux may continue into the future so that the TSWQS could be met. Potential risks to benthos and aquatic dependent wildlife are also expected to be reduced over time, likely to acceptable levels within an acceptable time frame over the majority of the Site. Alternative 2 includes the monitoring necessary to evaluate and assess the rate of MNR, which allows for an adaptive management approach wherein future actions would be considered depending on the effectiveness of MNR in achieving RAOs within a reasonable time frame.

The analytic model presented in Appendix E indicates that the TSWQS PCB standard of 30 ng/L would likely be met throughout the Site within 2 to 7 years, (subject to uncertainty considerations for this particular model) if the rates of decline for PCBs in surface water remain similar to those observed between 2009 and 2014. This uncertainty would be addressed through pre-design sampling, which would be used to assess the validity of the FS modeling.

The chemical fate model presented in Appendix A, coupled with the baseline mean PEL-Q and toxicity data, suggests that most of the Site would achieve acceptable benthic and aquatic dependent wildlife risk through ongoing natural recovery within 10 years; however some areas of the Site may have unacceptably long recovery periods. To address uncertainty, benthic risk natural recovery would need to be assessed through additional data collection and natural recovery evaluations. These evaluations would be used to assess whether additional action(s) is/are warranted though an adaptive management process.

5.2.1.2 Compliance with ARARs

Alternative 2 would not result in construction impacts or other changes to baseline conditions that would trigger any action-, chemical-, or location-specific ARARs identified in Table 3-2. Because no construction activity is included in this alternative, there are no substantive permit conditions that would need to be met.

5.2.2 Balancing Criteria

5.2.2.1 Long-term Effectiveness

Modeling conducted for this FS Report (Appendix E) indicates that the TSWQS would be met throughout the Site after 2 to 7 years due to natural recovery processes. The effectiveness would be monitored through periodic sampling of the water column to confirm that the TSWQS is being met.

The ability of natural recovery alone to meet benthic risk RAOs is uncertain. Modeling presented in Appendix A indicates that most of the Site would achieve acceptable benthic risk within 10 years due to natural recovery. However, approximately 9 acres encompassing nine surface sediment stations described in Section 4.3.2 may have unacceptably long recovery periods. Uncertainty in natural recovery to address benthic risk would need to be assessed by collecting additional data and updating and refining the natural recovery evaluations.

MNR has been demonstrated to be a reliable process that is effective in the long-term based on monitoring conducted at other sediment cleanup sites (USEPA 2005).

5.2.2.2 Reduction of Toxicity, Mobility or Volume

Alternative 2 does not take specific active measures to reduce TMV of COCs. The toxicity of surface sediments will naturally decline over time due to deposition of relatively clean sediments within the bayou.

5.2.2.3 Short-term Effectiveness

Alternative 2 ranks uncertain for short-term effectiveness. While analytic MNR modeling (Appendix E) predicts that natural recovery could take on the order of 2 to 7 years to achieve the TSWQS, natural recovery to address benthic risk could potentially require unacceptably long time frames. Natural recovery modeling is subject to uncertainty that would be addressed through pre-design sampling. Longer time frames to achieve RAOs are balanced by negligible short-term impacts associated with implementing this alternative; benthic, water and sediment sampling can be performed with very low risk to workers, and would have negligible short-term impacts on water and air quality. Noise impacts associated with Alternative 2 are also considered negligible.

5.2.2.4 Implementability

Alternative 2 is highly implementable. This alternative requires periodic monitoring through benthic, water and sediment sample collection, which has already been performed in support of the RI/FS. There are minimal anticipated implementability challenges associated with this alternative, which are limited to the coordination and safety issues associated with sample collection adjacent to active industrial operations bordering the bayou.

5.2.2.5 Cost

Alternative 2 entails periodic sampling of benthos, water and sediment. The estimated net present value (NPV) cost for Alternative 2 is $710,000 as detailed in Appendix C.

5.3 Alternative 3 – Monitored Natural Recovery, SMA-1 Capping, and SMA-2 through SMA-6 Treatment

5.3.1 Threshold Criteria

5.3.1.1 Overall Protection of Human Health and the Environment

Alternative 3 meets the threshold criterion of overall protection of human health and the environment because it is based on the same use of MNR as Alternative 2, and allows for capping of SMA-1 if warranted to achieve the TSWQS and treatment of SMA-2 thorough SMA-6 to reduce benthic and aquatic dependent wildlife risks, if/as needed. By capping SMA-1, potential sources of PCBs to the water column in that upstream area are effectively eliminated. Treatment of surface sediments in SMA-2 through SMA-6, if necessary, would reduce bioavailability of secondary ICs and reduce benthic and aquatic dependent wildlife risk to acceptable levels. Modeling presented in Appendix A indicates that capping SMA-1 is expected to achieve the TSWQS standard of 30 ng/L throughout the Site within 1 to 2 years following completion of capping.

Treatment of benthic risk areas is expected to reduce bioavailability of ICs relatively quickly. Field scale studies conducted on the Grasse River demonstrated that within 3 years after placement of AC into sediments, PCB bioavailability was reduced by more than 90 percent (Patmont et al. 2014). ITRC guidance recognizes that treatment can provide "near-immediate reduction of the bioavailable fraction of contaminants" with minimal impacts to habitat (ITRC 2014), although the mixing of treatment reagents into surface sediments would be expected to temporarily eliminate the benthic community, requiring up to a year following construction before the benthic community reestablishes itself.

5.3.1.2 Compliance with ARARs

Implementation of Alternative 3 would involve the construction of a low-profile cap within a portion of the Site, and treatment of benthic risk SMAs. Reduction of PCB concentrations in surface water would address TSWQS and also reduce risk to aquatic dependent wildlife. The construction of the cap and addition of AC to sediments would trigger compliance with CWA Section 404(b)(1), Rivers and Harbors Act Section 10, and other ARARs related to surface water quality. However, Alternative 3 is expected to meet the substantive requirements of the ARARs in Table 3-2 through implementation of BMPs and agency documentation and coordination activities. Construction of the cap would require the placement of approximately 1.6 acres of ACBM, a low-profile cap that is expected to have negligible impact on the flood capacity of Patrick Bayou (i.e., the impact of the cap would be immeasurable within the predictive capability of available flood models). If the cap in SMA-1 is required, there would be moderate impacts on habitat quality, as the banks of the area to be capped are already channelized with a concrete-lined surface, and thus the benthic community impacts would be limited to the bottom of the channel. Treatment of approximately 4.3 acres of sediment can be accomplished with a significant but temporary impact to habitat in the treatment footprint; recovery from these impacts would be expected to occur within approximately a year following completion of treatment.

5.3.2 Balancing Criteria

5.3.2.1 Long-term Effectiveness

Alternative 3 includes capping, if necessary, which is a robust technology that has been demonstrated to be effective in the long-term at many sediment cleanup sites and has a well-established design process (USEPA 1998). Modeling conducted for this FS Report (Appendix A) indicates that the TSWQS would be met throughout the Site within 1 to 2 years after completion of construction for Alternative 3. Treatment of benthic risk areas, if necessary, is expected to reduce bioavailability very quickly (within less than 3 years based on field scale demonstrations) in surface sediments, and may result in permanent[10] sequestration of key risk ICs. As described for Alternative 2, MNR has been demonstrated to be a reliable process that is effective in the long-term based on monitoring conducted at other sediment cleanup sites (USEPA 2005). Because treatment can be effective in relatively short time frames, there is little risk for an erosion event to occur before treatment is complete. The STM predicts maximum net erosion of less than 2 cm (less than 1 inch) for a 2-year recurrence interval storm (Anchor QEA 2011c). Because treatment would be conducted within the upper 6 inches (15 cm), treatment media would still be present even following an erosion event. Once treatment processes are complete, erosion of the treated media is not a concern.

Alternative 3 is highly compatible with adaptive management strategies that would facilitate modifying the monitoring plan and schedule, and/or allow for future actions to be taken if the results of the monitoring indicate additional remedial action is required. For example, if treatment were implemented to address benthic risk, treated areas could potentially be re-addressed in the future, if necessary (for example by adding additional amendments into sediments), if post-treatment monitoring indicated that benthic risk reductions were not being achieved quickly enough.

5.3.2.2 Reduction of Toxicity, Mobility or Volume

Alternative 3 provides for reduction in mobility of PCBs by including a treatment layer within the cap in SMA-1, and by treatment of surface sediments in benthic risk areas, if implemented. Appendix B describes the modeling performed assuming the use of a granular AC layer in the form of a RCM underlayment to the ACBM armored cap. Modeling indicates that this treatment is expected to reduce near-surface porewater concentrations of

[10] Because treatment is a relatively new approach to contaminated sediments, there is some uncertainty about the long-term performance of treatment remedies. There is no case history of monitoring that documents the long-term effectiveness of sediment treatment. Nonetheless, recent literature supports the use of treatment as a sediment remedial technology, and treatment is expected to be effective in the long-term for Patrick Bayou.

PCBs by 99.8 percent over 100 years. Case studies of AC treatment of sediments demonstrate potential PCB concentration reductions of more than 99 percent, and PCB bioavailability reductions of more than 90 percent in treated sediments (Patmont et al. 2014).

5.3.2.3 Short-term Effectiveness

Short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative include:

- Potential turbidity (manageable) associated with cap construction;
- Potential turbidity (manageable) during treatment;
- Moderate benthic impacts in ACBM capping areas, which would require several years of sediment deposition onto the surface of the ACBM before benthic recovery could occur;
- Significant but temporary benthic impacts in treatment areas due to mixing of near surface sediments, which would require up to a year following treatment before benthic recovery would occur;
- Localized impacts to the banks of the bayou where construction equipment would be staged and where the ACBM cap would be anchored;
- Potential accidents during construction;
- Air emissions from construction equipment;
- Noise impacts from the work;
- Potential facility impacts during the estimated 5 to 7-month duration of the work.

Water quality impacts would be expected to be manageable based on case history of implementing ACBM capping and treatment at other sites, associated with turbidity during debris removal activities within the bayou, cap construction, and mixing of treatment reagents into surface sediments.

Air quality impacts are expected to be moderate for this alternative, associated with equipment operations and truck traffic. An estimated 3,050 hours of heavy equipment operations would be required to complete the project. Equipment and vehicle emissions of hydrocarbons and nitrogen oxides lead to the generation of smog, including ozone, which is a particular concern in Harris County which has been classified by USEPA as a “severe” non-attainment area for the 1997 8-hour ozone standard and a "moderate" non-attainment area for the 2008 8-hour ozone standard. Moreover, Harris County has not yet been classified for the 2012 fine particle particulate matter (PM2.5) annual National Ambient Air Quality Standard (TCEQ 2013).

Community impacts associated with truck traffic are expected to be negligible considering that the Site is located in an industrial area.

Health and safety impacts were assessed using U.S. Department of Labor statistics for accidents and fatalities for the "construction" labor code category, based on the estimated total labor hours required for the alternative. Alternative 3 would result in an estimated 0.017 lost-time injuries and 0.0007 fatalities. While both of these safety statistics are below 1.0 suggesting the likelihood for injury or fatality is very low, they are useful for comparison purposes to the safety-related issues of the other alternatives. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks.

5.3.2.4 Implementability

Capping using ACBM and RCM products has been successfully demonstrated at similar sites. The shallow water and relatively narrow channel should provide for relatively straightforward deployment of the textiles. There are several areas with difficult access, such as pipeline crossings and bridge foundations, where hand labor would be required to deploy the fabric prior to pumping concrete into the ACBM formwork. Because the ACBM has a low profile it is not expected to materially impact the flood capacity of the bayou based on the areas estimated for this alternative.

Treatment by mixing AC into sediments has been demonstrated at field scale on several sediment projects. Custom equipment may be required for mixing reagents, and an experienced contractor would be recommended to perform treatment mixing. Access to the center of the channel, while challenging, could be facilitated by using small, shallow-draft barges. Turbidity caused by mixing could present an implementability challenge. This turbidity could be managed using BMPs and engineering controls such as silt curtains. Details on turbidity controls would be developed during remedial design.

Additional implementability challenges include the need to coordinate with the railroad during design and construction in SMA-1. In addition, different ACBM anchoring details may be needed at the top of the bank due to the variable Site conditions (presence of utilities, fences, more natural ground, or active production facilities) along the banks of SMA-1. Finally, remedial construction in the bayou adjacent to active production facilities would be an implementability challenge for scheduling the work, obtaining access to the work areas through active production areas, limited available space on the banks of the bayou, and providing for remedial contractor safety. None of these challenges are expected to be insurmountable but may impact cost and schedule.

5.3.2.5 Cost

Costs for this alternative were estimated as described in detail in Appendix C. Costs include direct construction costs (mobilization/demobilization, Site preparation, installation of environmental controls, survey, debris removal, and capping) and indirect construction costs (permitting, engineering and design, construction oversight, long-term operations, monitoring, and maintenance [OMM], and USEPA periodic reviews). Future costs such as OMM and periodic reviews were estimated on an NPV basis, assuming a discount rate of 7 percent.

The estimated cost for Alternative 3 is approximately $6 million.

5.4 Alternative 4 – Monitored Natural Recovery and SMA-1 through SMA-6 Capping

5.4.1 Threshold Criteria

5.4.1.1 Overall Protection of Human Health and the Environment

Alternative 4 meets the threshold criterion of overall protection of human health and the environment because it is based on the same use of MNR as Alternative 2, and allows for capping of SMAs 1 through 6, if warranted, to achieve the TSWQS and to manage benthic risk in these areas. By capping SMA-1, potential sources of PCBs to the water column would be effectively contained. Capping SMA-2 through SMA-6 would effectively eliminate the exposure pathway between benthos and sediments be creating a hard barrier on the sediment surface. Modeling presented in Appendix A indicates that by capping these areas (specifically SMA-1), the Site would be expected to achieve the TSWQS standard of 30 ng/L, within 1 to 2 years following completion of construction. Benthic risk would be reduced within 10 years following completion of construction, and aquatic-dependent wildlife risk would be reduced due to a reduction in the availability of PCBs to bioaccumulate. However, capping would effectively eliminate the benthic community for years, especially in down stream areas where benthic conditions are more conducive to supporting some benthic organisms.

5.4.1.2 Compliance with ARARs

As with Alternative 3, implementation of Alternative 4 would reduce PCB concentrations in surface water, addressing the TSWQS and would also lower risk to aquatic dependent wildlife. Construction of a low-profile cap would trigger compliance with CWA Section 404(b)(1), Rivers and Harbors Act Section 10, and other ARARs related to surface water quality. However, Alternative 4 is expected to generally meet the substantive requirements of the ARARs in Table 3-2 through implementation of BMPs and agency documentation and coordination activities. Construction of the cap would require the placement of approximately 11.7 acres of low-profile ACBM, which is expected to have negligible impact on the flood capacity of Patrick Bayou (i.e., the impact of the cap would be immeasurable within the predictive capability of available flood models).

Unlike Alternative 3, up to 10.1 acres of shallow-water habitat in SMAs 2 through 6 would potentially be capped under Alternative 4. This would result in the immediate elimination of the existing benthic habitat in these SMAs. Although these impacts would be temporary, benthic recovery could require several years before a significant thickness of new sediment were to be deposited onto the surface of the cap to create a suitable habitat substrate. Mitigation for habitat impacts may be required, which would significantly increase the cost of implementing Alternative 4.

5.4.2 Balancing Criteria

5.4.2.1 Long-term Effectiveness

As with Alternative 3, Alternative 4 also includes capping, which has been demonstrated to be effective in the long-term at many sediment cleanup sites. Modeling conducted for this FS Report (Appendix A) indicates that the TSWQS would be met throughout the Site within 1 to 2 years after completion of construction, and benthic risk would be reduced within 10 years following completion of construction for Alternative 4. As described for Alternatives 2 and 3, MNR has been demonstrated to be a reliable process in the long-term.

In addition to capping and natural attenuation processes, the adaptive management approach taken under Alternative 4 would facilitate modifying the monitoring plan and schedule, and/or allow for future actions to be taken if the results of the monitoring indicate additional remedial action is required. However, capping with ACBM would allow for fewer future options to be considered in capped areas because the hard concrete surface would preclude actions such as in situ treatment once the cap was in place.

5.4.2.2 Reduction of Toxicity, Mobility or Volume

Similar to Alternative 3, Alternative 4 provides for reduction in mobility of PCBs by including a treatment layer within the cap in SMA-1. This alternative assumes the use of a granular AC layer dosed at the same rate as Alternative 3, in the form of a RCM underlayment to the ACBM armored cap in SMA-1, which is expected to reduce near-surface porewater concentrations of PCBs by 99.8 percent over 100 years (Appendix B). Unlike Alternative 3, there is no treatment component in SMAs 2-6 under this alternative.

5.4.2.3 Short-term Effectiveness

Short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative include:

- Potential turbidity (manageable) associated with cap construction;
- Significant benthic impacts in ACBM capping areas, which would require several years of sediment deposition onto the surface of the ACBM before benthic recovery could occur. These impacts would occur even beyond the identified SMA footprint

because of the need to extend the ACBM to the top of bank for anchoring as described in Section 4;

- Widespread impacts to the banks of the bayou where construction equipment would be staged and where the ACBM cap would be anchored;
- Potential accidents during construction;
- Air emissions from construction equipment;
- Noise impacts from the work;
- Potential facility impacts during the estimated 5 to 7-month duration of the work.

Water quality impacts would be expected to be negligible, associated with turbidity during debris removal activities within the bayou, and cap construction.

Air quality impacts are expected to be moderate for this alternative, associated with equipment operations and truck traffic. An estimated 3,250 hours of heavy equipment operations would be required to complete the project. Equipment and vehicle emissions of hydrocarbons and nitrogen oxides lead to the generation of smog, including ozone, which is a particular concern in Harris County which has been classified by USEPA as a "severe" non-attainment area for the 1997 8-hour ozone standard and a "moderate" non-attainment area for the 2008 8-hour ozone standard. Moreover, Harris County has not yet been classified for the 2012 fine particle particulate matter (PM2.5) annual National Ambient Air Quality Standard (TCEQ 2013).

Community impacts associated with truck traffic are expected to be minimal considering that the Site is located in an industrial area.

Health and safety impacts were assessed using U.S. Department of Labor statistics for accidents and fatalities for the "construction" labor code category, based on the estimated total labor hours required for the alternative. Alternative 4 would result in an estimated 0.17 lost-time injuries and 0.0007 fatalities. As with Alternative 3, both of these safety statistics are below 1.0 suggesting the likelihood for injury or fatality is very low. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks.

5.4.2.4 Implementability

As discussed under Alternative 3, capping using ACBM and RCM products has been successfully demonstrated at similar sites. Areas with shallow water and/or a relatively narrow channel should provide for relatively straightforward deployment of the textiles. In difficult access areas, such as pipeline crossings and bridge foundations, hand labor can be used to deploy the fabric prior to pumping concrete into the ACBM formwork. Because the ACBM has a low profile it is not expected to materially impact the flood capacity of the bayou. However, if it is determined during remedial design that dredging is necessary to maintain flood capacity in the bayou, the implementability challenges would be significant, including protection of water quality, management of residuals and releases, material handling, and disposal as described in Section 4.2.5.

Implementability challenges include the need to coordinate with the railroad during design and construction in SMA-1. In addition, different anchoring details may be needed at the top of the bank due to the variable Site conditions (presence of utilities, fences, more natural ground, or active production facilities) along the channel length. Further, in wider channel areas the contractor may need to take additional measures to ensure that the pumped grout will fully fill the ACBM formwork in the middle of the channel, because the grout hoses are typically inserted into the formwork at the edge of the mat, on top of the banks. These wider panels of formwork are also more difficult to deploy accurately because of their size. Finally, remedial construction in the bayou adjacent to active production facilities would be an implementability challenge for scheduling the work, obtaining access to the work areas through active production areas, limited available space on the banks of the bayou, and providing for remedial contractor safety. None of these challenges are expected to be insurmountable but may impact cost and schedule.

5.4.2.5 Cost

Costs for this alternative were estimated as described in detail in Appendix C. As with the other alternatives, costs include direct construction costs and indirect construction costs, and long-term costs are estimated on a NPV basis.

The estimated cost for Alternative 4 is approximately $10.7 million.

6 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the alternatives relative to each of the FS evaluation criteria listed under the NCP. Table 5-1 summarizes the criteria for each alternative and provides the basis for the comparative evaluation discussion in this section. Table 6-1 provides a comparative evaluation summary for the alternatives, in the form of a relative ranking of each alternative against the others.

6.1 Threshold Criteria

6.1.1 Overall Protection of Human Health and the Environment

Alternative 1 does not meet the threshold criterion for overall protection of human health and the environment. Thus it was excluded from further consideration in this comparative evaluation.

Preliminary model predictions conducted for this FS indicate that Alternative 2 is uncertain as to whether it can achieve overall protection of human health and the environment. Alternative 2 is estimated (albeit with some uncertainty as described in Appendix E) to achieve the TSWQS throughout the Site after 2 to 7 years through natural recovery, however benthic risk may not be reduced to acceptable levels across the entire Site within a reasonable time frame as described in Appendix A.

Alternatives 3 and 4 provide for protection of human health and the environment through combinations of natural recovery, treatment and capping. Alternatives 3 and 4 are expected to meet the TSWQS within 1 to 2 years after construction (Appendix A). Alternative 3 is estimated to reduce aquatic dependent wildlife and benthic risks to acceptable levels within less than 3 years following construction, and Alternative 4 is estimated to reduce aquatic dependent wildlife and benthic risks within 10 years following completion of construction, albeit over a longer period than Alternative 3 because Alternative 4 relies on sedimentation to occur over significant areas of ACBM cap before benthic habitat recovery has occurred.

6.1.2 Compliance with ARARs

Alternative 2 is uncertain in regards to natural recovery's ability to meet the TSWQS, although recent surface water sampling data indicate reductions in PCB concentrations that, if this trend continues, would achieve the TSWQS throughout the Site within 2 to 7 years. Because Alternative 2 does not entail active construction in the bayou, other ARAR compliance is expected to be more straightforward than for Alternatives 3 and 4.

Alternatives 3 and 4 are both expected to comply with ARARs. Implementation of Alternative 3 or 4 would require the use of BMPs to protect surface water quality during construction and conform to substantive requirements of ARARs. Alternative 4 has a higher potential ecological impact than Alternative 3 because it potentially requires the use of a larger ACBM cap; as such, implementation of Alternative 4 could trigger a need for mitigation for loss of shallow-water habitat, which would significantly increase the cost and time frame for this alternative.

6.2 Balancing Criteria

6.2.1 Long-term Effectiveness

Alternative 2 ranks uncertain for long-term effectiveness. Based on modeling conducted for the FS, the TSWQS may not be fully achieved across the Site until year 7 under natural recovery alone. In one location (PB-032, Table 4-1), it is estimated that over 40 years of natural recovery would be required before benthic risk is reduced to acceptable levels based on empirical model projections (Appendix A).

Alternative 3 and Alternative 4 rank the highest for long-term effectiveness, and are considered the same for long-term effectiveness. Both are predicted to meet the TSWQS throughout the Site within 1 to 2 years following remedy construction based on the results of the modeling presented in Appendix A. Residual aquatic dependent wildlife and benthic risk is projected to be reduced to acceptable levels within less than 3 years under Alternative 3, and this alternative is highly compatible with adaptive management options that allow for future actions to be taken to ensure the long-term effectiveness of the remedy. Under Alternative 4, benthic risk is reduced to acceptable levels following completion of construction because the exposure pathway between benthos and sediment is predicted to be blocked; however benthic recovery would require longer under Alternative 4 because new sediment input would be needed to improve the habitat substrate on the surface of the ACBM cap. Finally, Alternative 4 provides fewer opportunities to implement adaptive management actions in capped areas because the ACBM cap is a relatively permanent structure.

6.2.2 Reduction of Toxicity, Mobility or Volume

Alternative 2 does not include additional measures to reduce TMV beyond the natural sedimentation processes that are expected to reduce the mobility of impacted surface sediments and continued attenuation of the source of PCBs to the water column. Alternatives 3 and 4 include a treatment layer (granular AC within a RCM) below the armored cap in SMA-1, which will sequester PCBs and is expected to reduce near-surface porewater concentrations by 99.8 percent over 100 years where the RCM is used. Alternative 3 provides additional treatment of contaminants in benthic risk SMAs through the use of in situ treatment, which, based on case studies, could be expected to reduce PCB concentrations in surface sediment porewater by up to 99 percent or more, and reduce bioavailability by at least 90 percent. Because of the additional treatment provided under Alternative 3, it ranks higher than Alternative 4 for reduction of TMV.

6.2.3 Short-term Effectiveness

Alternative 2 ranks uncertain for short-term effectiveness. Although there are no active construction activities and the work is limited to sample collection for MNR monitoring (and thus short-term environmental impacts, community impacts, and health and safety impacts are negligible), the time frame to meet the TSWQS is estimated to be 2 to 7 years, and the time frame for benthic risk to reach acceptable levels could be unacceptable across some parts of the Site. Both estimates are subject to the uncertainty associated with the analytical models used for these predictions.

Alternative 3 ranks higher than Alternative 4 for short-term effectiveness, and both rank higher than Alternative 2 because they achieve the TSWQS within 1 to 2 years after construction, and achieve aquatic dependent wildlife and benthic risks reduction either within 3 years (Alternative 3), or within 10 years (Alternative 4) to allow for sediment deposition to create a suitable habitat substrate in the surface of the ACBM cap. Alternatives 3 and 4 cause disturbance along the bayou at the top of the bank to facilitate ACBM anchoring – however under Alternative 4 this disturbance is much more widespread. Based on estimated environmental impacts, as reflected by equipment operation hours and truck trips, the impacts from Alternative 4 are estimated to be essentially the same as Alternative 3. Alternative 3 has a slightly higher potential for water quality impacts than Alternative 4 because it entails mixing of a treatment reagent into surface sediments. However, if surficial application of AC is used for treatment in lieu of mixing, turbidity would be greatly reduced. The risk of health and safety impacts, as reflected by potential lost time injuries or fatalities is also comparable between Alternative 3 and Alternative 4. Because the potential short-term impacts are relatively lower for Alternative 3 (specifically considering the benthic disturbance following construction) it ranks higher than Alternative 4 for short-term effectiveness.

6.2.4 Implementability

Alternative 2 ranks highest for implementability. Benthic, water and sediment sample collection has been performed at the Site successfully with negligible impact to ongoing operations, using relatively straightforward techniques. Because there is no active construction, there are no implementability concerns such as site access for Alternative 2.

Alternative 3 ranks comparably to Alternative 4 for implementability. Placement of an ACBM cap over approximately 1.6 acres in SMA-1 under both alternatives is considered technically feasible for an experienced contractor, albeit with similar implementability challenges associated with working adjacent to active production facilities as described in Section 5. Although the use of ACBM requires less experienced contractor personnel and more traditional construction equipment compared to the specialized equipment that might be needed to implement treatment in SMA-2 through SMA-6, capping could trigger the need for excavation to maintain flood capacity (see Section 4) which would exacerbate implementability and offset any advantage of the more traditional construction approach.

6.2.5 Cost

Alternative 2 is the lowest cost alternative, with an estimated cost of $710,000 NPV. Alternative 3 is estimated to cost approximately $6 million NPV, a factor of more than 8 times greater than Alternative 2. Alternative 4 is estimated to cost approximately $10.7 million NPV, a factor of more than 15 times greater than Alternative 2, and more than 75 percent greater than Alternative 3.

While Alternative 2 has the lowest cost, there is some uncertainty around the modeling used to assess Alternative 2 that would not be confirmed until pre-design sampling. For the remedies that include active construction, Alternative 3 is more cost-effective than Alternative 4, as defined under both CERCLA and the NCP, which require that remedies be cost-effective (42 U.S.C. §9621(a); 40 CFR §300.430(f)(1)(ii)(D)). "Each remedial action selected shall be cost-effective." Alternative 3 effectively and permanently reduces risk in a cost-effective manner when compared to Alternative 4. With a similar restoration time frame compared to Alternative 3, Alternative 4 does not provide any material incremental risk reduction, and is less compatible with future adaptive management actions than Alternative 3.

6.3 Summary of Comparative Evaluation

Table 6-1 presents a comparison matrix providing a qualitative ranking of Alternatives 2, 3, and 4 using a the terms "least favorable" "middle" and "most favorable" to indicate each alternative's rank relative to one another for a particular criterion. An additional category, "uncertain" is also included to indicate that RI/FS evaluations are not sufficient to compare the alternative relative to the others until pre-design, baseline sampling data are collected.

These qualitative rankings are based on the discussion provided in Sections 6.1 and 6.2, and the detailed considerations described in Section 5 and presented in Table 5-1. In some cases, alternatives are ranked the same for a particular criterion. Note that Table 6-1 does not consider State or community acceptance, which are considered by USEPA during preparation of the proposed plan for the Site.

As is shown in this table, and based on the data available at the time of the FS, Alternative 3 ranks higher overall as compared to Alternative 4 when compared directly, and provides for higher certainty of outcome than Alternative 2.

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TABLES

Table 3-1
Sediment Toxicity and Chemistry Lines of Evidence as Presented in the BERA

2002/2003 Benthic Toxicity Station	Proportion Toxic	Toxicity Classification	2002/2003 Mean PEL-Q
V	0%	Low	1.25
2.5	0%	Low	1.37
S	0%	Low	3.26
E	25%	Low	1.98
U	0%	Low	0.14
3	***31%***	***Indeterminate***	***7.56****
G	25%	Low	0.74
4A	54%	Probable	56.12
5	25%	Low	3.07
T	0%	Low	1.53
6A	69%	Probable	12.17
Q	25%	Low	4.47

Notes:
* Lowest mean PEL-Q with indeterminate toxicity

Table 4-1
Mean PEL-Q and Half-Life Evaluation

Location	2009 Mean PEL-Q	Scenario 1 No Action Taken in SMA-1 (Alternatives 1 and 2)		Scenario 2 Capping in SMA-1 (Alternatives 3 and 4)	
		Half Life – Natural Recovery Only (years)	Time Needed to Reach Mean PEL-Q Threshold (years)	Half Life – Remediation of SMA-1 (years)	Time Needed to Reach Mean PEL-Q Threshold (years)
PB-026	166.5	5	22	5	22
PB-032	80.7	13	44	12	41
PB-036	15.9	13	14	12	13
PB-037	13.9	13	11	12	11
PB-047.1	26.7	9	16	7	13
PB-053A	129.7	5	20	2	8
PB-059.1	62.5	5	15	2	6
PB-063.1	43.4	5	13	3	8
PB-069	58.8	5	15	3	9

Table 4-2
Summary of SMA Delineation

ID	Location	Acreage	Reason for Delineation
SMA-1	PB-075 to PB-082	0.63	TSWQS
SMA-2	PB-032	0.73	Benthic Risk PRG
SMA-3	PB-026	0.79	Benthic Risk PRG
SMA-4	PB-047.1	1.31	Benthic Risk PRG
SMA-5	PB-036	0.70	Benthic Risk PRG
SMA-6	PB-037	0.74	Benthic Risk PRG
Natural Recovery Areas	See Figure 4-1	16.92	Baseline mean PEL-Q exceeds PRG

Notes:
1. SMA-2 through SMA-6 were delineated using MNR rates that assume potential downstream loading of PCBs from SMA-1 is resolved.
2. Acreage based on Thiessen polygon areas. For FS cost purposes, a 20 percent contingency has been added and additional area has been added to account for bank-to-bank capping where ACBM is used. Thus, the areas presented in the Appendix C costs do not match the areas presented in this table.

Table 4-3
Aggregate Cap Armor Sizing

SMA	Cap Armor Stone d_{50} (inches)[1]	Minimum Armor Layer Thickness (feet)[2,3]
1	37	6.5
2	8	1.5
3	9	1.5
4	0.5	0.25
5	6	1.0
6	6	1.0

Notes:

1. d_{50} based on the 100-year storm event.
2. Minimum armor layer thickness shown for SMA-1, -2, -3, -5 and -6 based on 2*d_{50} dimension.
3. Minimum armor layer thickness for SMA-4 shown as the thinnest layer considered reasonably constructible, which is greater than the thickness determined based on the 2*d_{50} dimension.

Table 6-1
Comparative Evaluation of Remedial Alternatives

Criterion	Alternative 2 MNR	Alternative 3 MNR, SMA-1 Capping and SMA-2 through SMA-6 Treatment	Alternative 4 MNR and SMA-1 through SMA-6 Capping
Overall Protection	Uncertain	Similar to Alternative 4	Similar to Alternative 3
Compliance with ARARs	Uncertain	Most Favorable	Middle
Long-term Effectiveness	Uncertain	Similar to Alternative 4	Similar to Alternative 3
Reduction in TMV	Least Favorable	Most Favorable	Middle
Short-term Effectiveness	Uncertain	Most Favorable	Middle
Implementability	Most Favorable	Similar to Alternative 4	Similar to Alternative 3
Cost	Most Favorable	Middle	Least Favorable

Notes:
ARARs = Applicable or Relevant and Appropriate Requirements
MNR = Monitored Natural Recovery
TMV = Toxicity, Mobility or Volume